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# ADJUSTMENT OF ENGINE VALVES AND GOVERNORS

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PLANT ENGINEERING HANDBOOKS

# *Adjustment of Engine Valves and Governors*

TECHNICAL PUBLISHING CO.
Chicago, Ill.

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# CHAPTER I

## GENERAL PRINCIPLES OF ENGINES

IN THE development of steam engines there have been certain definite trends which have had to do mainly with the methods of getting the steam into the cylinders, utilizing it as efficiently as possible and then exhausting the steam, either to the atmosphere or to a condenser. In this development the simple slide valve was the first method of controlling the admission and the exhaust of the steam. Later on came the balanced types of valves such as the piston and then a still further development was the riding cut-off valve. Another important step was the use of Corliss valves of the releasing type and then came valves similar to the Corliss but of a non-releasing type.

### Use of Unaflow Principle

All of these developments had to do mainly with getting the steam into the cylinder as no changes of any great consequence were involved in getting the steam out of the cylinder, since the same general principles were involved in the use of all of these types of valves, that is, the steam reversed itself on the exhaust stroke. The engines, in other words, were of the counter-flow type. The next big development was, therefore, that of exhausting the steam at the center of the cylinder so that no reversal of steam flow was necessary. This type of engine known as the unaflow was the result of this further step in steam engine design.

### The Slide Valve

In the earliest forms of steam engines simple slide valves of the D type were used. The arrangement, as originally used was similar to that shown in Fig. 1 with the ends of the valves the same width as the ports so that the valve just covered the ports when in mid position. With this mechanism the center of the eccentric had to be at the 90-deg. point on the eccentric circle so that the valve

would be in central position when the piston was at the beginning of the stroke as shown in Fig. 1.

Suppose that the direction of running in this valve lay-out is as shown by the arrow. As soon as the shaft starts turning, the valve will be drawn to the right and the ports at the left hand or head end of the cylinder will be open for the entrance of steam. The port at the right hand, or crank end of the cylinder, begins to open for exhaust. The result is that the piston is forced to the right. The further the shaft turns, the more the valve will be moved to

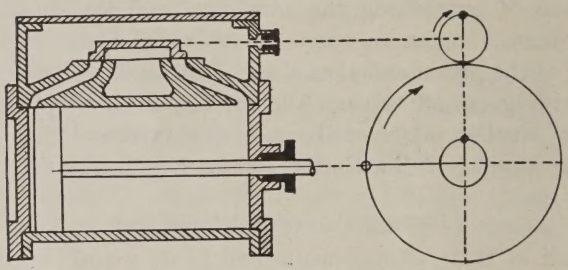


FIG. 1. POSITION OF D VALVE WITH PISTON AT HEAD END OF STROKE

the right, until the eccentric center reaches its extreme position at the right of the eccentric circle. Then the valve commences to move to the left. The force of the steam continues to push the piston to the right, however, until the valve again reaches mid position and the eccentric is directly at the bottom of the eccentric circle at which time the piston has reached its right hand dead point.

Continuing the motion, the eccentric moves the valve to the left which opens the right hand end of the cylinder to the steam and the left hand end to the exhaust, thus forcing the piston to the left. The valve opens wider as the shaft turns, until the eccentric reaches its left hand position. After that, the valve begins to close until the mid position of the valve is reached and the piston is at the extreme left as in Fig. 1, and conditions are as at the beginning.

## Why Valves Are Set With Lap

This arrangement will cause the engine to operate but it allows the steam to enter throughout the entire stroke, and no use is made of the work of expansion. This led to the use of a projection on the valve called lap, which extended beyond the edge of the port, on the outside end and tended to close the ports before the piston reached the end of the stroke, so that the steam had a chance to work expansively. Since this addition delayed the admission of steam at the beginning of the stroke, the eccentric

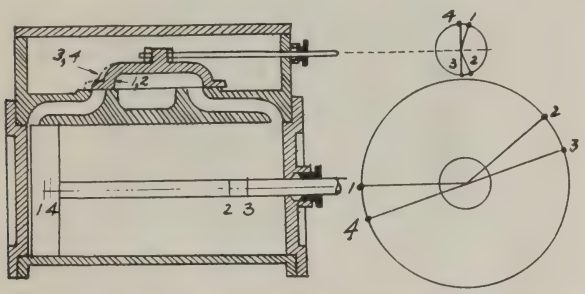



FIG. 2. D VALVE ACTION WITH ECCENTRIC ADVANCED TO CORRECT LATE ADMISSION DUE TO LAP

had to be turned on the shaft until the admission was brought back to the beginning of the stroke and this turning ahead still further advanced the cut-off of the steam. The times of opening and closing the ports with the lengthened valve are shown after the eccentric has been set ahead as in Fig. 2.

In this type of valve, the more that is added to the valve on the steam end, the earlier will be the cut-off. The eccentric, therefore, has to be turned further ahead to bring the admission at the proper place and this again makes the cut-off earlier. As the cut-off is thus made earlier the release of the steam begins earlier, and the closing of the exhaust and the beginning of compression occur earlier. These last two effects soon become so extreme as to be unsatisfactory.

When the valve has something added to it on the end it "laps" over the edge of the port as it stands in the middle position and the length that it projects over is

called the lap of the valve. The angle through which the eccentric is turned ahead to correct the admission after lap is added is called the "lap angle" and is measured ahead of the position the eccentric when there is no lap, which is 90 deg. ahead of the crank. Trial and experience show that the practical limit for cut-off with the D valve is about $\frac{5}{8}$ stroke.

Another defect of the simple D valve is that the pressure on the back is unbalanced and for large sizes, considerable power is used in friction between the valve and its

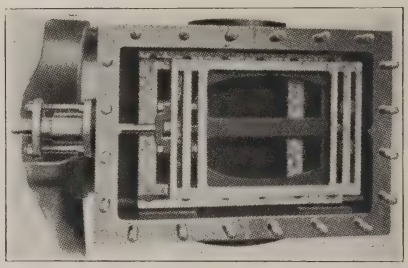


FIG. 3. BALANCED VALVE WHICH OPERATES BETWEEN SEAT AND A PRESSURE PLATE

seat. Another disadvantage is that the action of the valve in opening and closing is gradual so that free passage for steam is secured only after an appreciable interval.

### Development of the Balanced Valve

Several methods of balancing valves of this type have been used such as a pressure plate over the back of the valve which is carried on strips at the sides, opening being made through the valve, so that the same pressure acts on both sides. In Fig. 3 is shown a valve of this type.

Another method has been to use a piston valve with a cylindrical seat in order to equalize the pressure on all sides of the valve. Still another form of balancing is the two-part valve, arranged so that one face bears on the seat and the other on the steam chest cover, the parts being separated by steam pressure to maintain their bearings.

Quicker opening and closing were secured by the use of several openings at each end of the valve, or in multi-valved engines by a system of links to multiply the rapidity

of motion. The single valve does not lend itself readily to such multiplying action, and extreme rapidity of opening and closing are not of so great consequence for the exhaust events, as for the steam events.

### Use of Riding Cut-Off Valve

One of the next steps which was made to overcome the inherent defects of the slide valve in connection with cut-

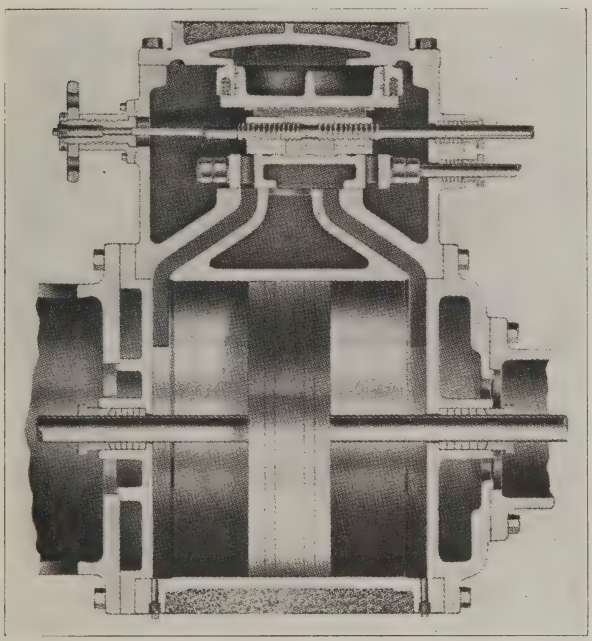


FIG. 4. SECTION OF A MEYER REDUCING CUT-OFF VALVE

off regulation was the development of a riding cut-off valve. In the simplest form, as shown in Fig. 4, this consists of a modified D valve having steam ports through the valve. Upon this main valve a smaller slide valve is operated by means of another eccentric and controlled by the governor so as to cut off the steam at varying points of the stroke depending upon the load. The eccentric for this rider valve travels ahead of that for the main valve, so that, at the time of cut-off, the rider is travelling in a

direction opposite to that of the main valve with a result that cut-off is rapid and wire drawing is minimized.

Among the advantages for this type of valve is the ease with which cut-off can be regulated by the governor. Being light in weight, little power is needed to operate the rider valve and the drag upon the governor in changing the position of the cut-off is slight so that the regulation

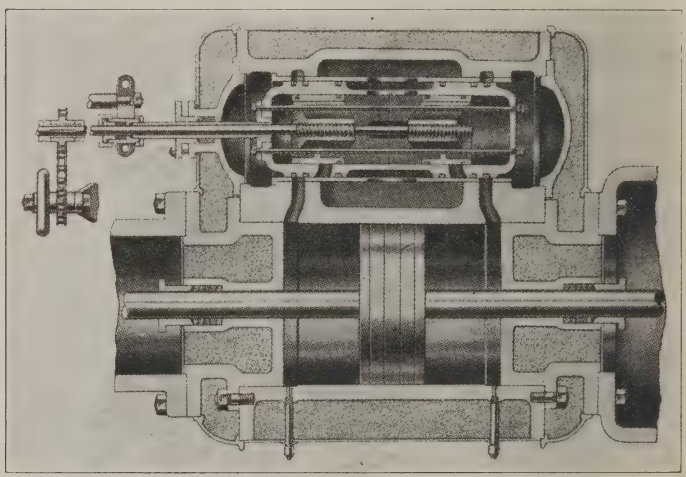


FIG. 5. RIDING CUT-OFF VALVE OF THE PISTON TYPE

secured by engines equipped with riding cut-off valves is close.

With this type of valve it is common to employ little or no steam lap on the main valve by which means it is possible to secure a wide range of cut-offs from 0 to ¾ stroke.

Piston valves are built on the same princples as the rider valve of the D type. In Fig. 5 is shown a typical riding cut-off piston valve.

### Corliss Valves Next Development

One of the next important developments in steam engine design was the use of the Corliss type of valves. The essential features of a Corliss engine are: First, its four semi-rotary valves, two of these being for steam admission and two for exhaust, with the latter placed at the

bottom of the cylinder to drain out condensation. Second, the employment of an eccentric on the main shaft, operating the valves through radial arms in such a manner as to obtain rapid opening and closing of the valves. Third, some means of releasing the steam valve from the driving mechanism at the proper point in the stroke and closing the valve quickly by means of vacuum dash-pots. Fourth,

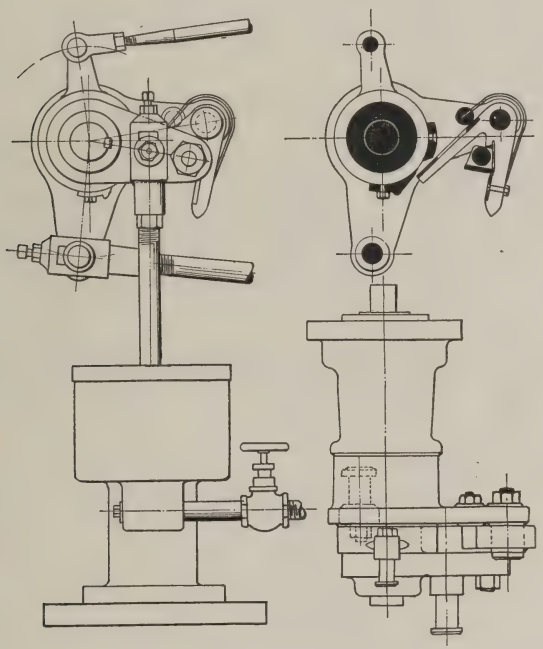


FIG. 6. RELEASING TYPE OF CORLISS VALVE MECHANISM

a governor driven from the main shaft and so arranged as to be entirely independent of the valve gear, its only purpose being to determine the point at which the release shall occur according to the load on the engine.

By means of right and left hand thread connections on the radial arm, any valve may be adjusted independently of the others and the amount of lead, point of exhaust and the amount of compression remain the same at whatever point of the stroke cut-off may occur, making it possible to obtain nearly ideal indicator diagrams. As the steam

valves are opened quickly by means of the bell-crank connection, wire drawing is avoided. Quick closing of the steam valve by the suction of the dash-pots further reduces wire drawing and allows expansive energy of the steam to be fully realized in the cylinder.

### Releasing Mechanism of Corliss Valve

The feature of the releasing gear, which is the most important part of the Corliss engine construction, is the hook or crab claw which engages a block on the valve-stem

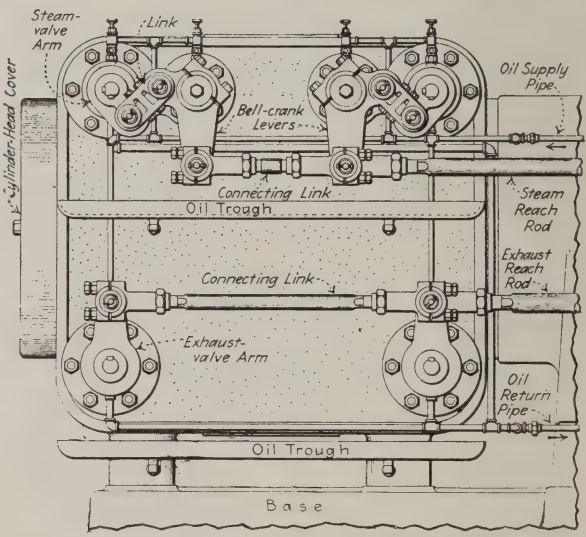



FIG. 7. NON-RELEASING VALVE GEAR OF THE CORLISS TYPE

crank arm raising the valve until the inner member of the hook comes in contact with the block, causing the valve to be released, thus cutting off the steam. Fig. 6 shows a typical Corliss valve mechanism. Numerous types of Corliss valves have been developed which differ from one another in the details of design. Some of these will be discussed in a later chapter, which takes up the study of valves of this type.

### Non-releasing Type of Corliss Valve

In order to get away from the releasing mechanism of the Corliss valve and yet take advantage of this type of

valve, the non-releasing type of Corliss valve was developed as shown in Fig. 7. Valves of this type are usually double ported to reduce the amount of valve travel necessary and to reduce the inertia of the moving parts, in order to permit higher rotating speed and higher steam pressures for a given size unit, without an increase in weight of the engine in proportion to the power development. Some successful engines have been constructed with triple-ported valves.

In the four-valve engine of this type, the main thought has been to secure a quick valve movement with as long a pause at each end of the travel as possible and in this way to secure the same result by a quick positive closing as is secured in the Corliss engine by releasing the valve and closing it by means of a dash-pot.

Initial cylinder condensation due to the heat exchange between the steam and cylinder walls has always been a source of thermal loss within the cylinders of reciprocating engines. This loss increased with longer time of contact, with greater temperature difference between the steam and the walls, and with the force of throw and whirl of the steam against the walls.

### Piston Becomes Exhaust Valve in Unaflow Engine

It was a desire to reduce this source of loss to a minimum that brought about the development of the Unaflow engine. This engine has a cylinder with exhaust ports at the center which are uncovered by the piston at about 0.9 of its outward stroke so that the valves are used only to admit steam.

This type of engine was experimented with by Eaton in the United States in 1857 and built by Todd in England in 1885 but was not a commercial success until 1908, when Professor Johannes Stumpf, of Charlottenburg, developed the engine along its present lines. The features are: 1. Exhaust ports in the center of and around the cylinder, at the end of stroke, which is the means of discharging most of the exhaust and eliminating the counter flow of cool expanded wet steam. 2. An elongated piston functioning as exhaust valves. 3. Steam jacketed cylinder heads maintaining hot cylinder ends and imparting heat to the com-

pression steam. In Fig. 8 is shown a cross section of the cylinder of a unaflow engine.

While the general arrangement of the valves for the the unaflow engine is somewhat similar to that of others there are certain features which require a somewhat different line of approach from that for the slide valve, piston valve, or Corliss types. Where, for instance, the unaflow engine is intended to operate condensing, automatic compression relief valves must be provided as a safety device to relieve the excessive compression pressure

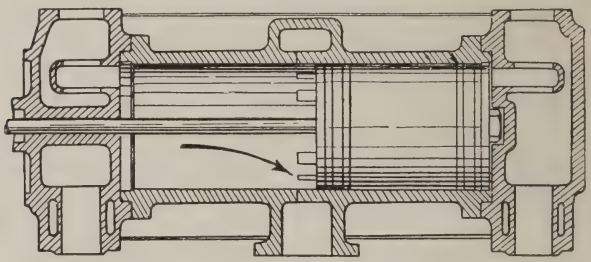


FIG. 8. STEAM EXHAUSTS THROUGH CENTER PORTS IN UNAFLOW ENGINE CYLINDER

in case the vacuum should become too low, or fail altogether. The reason that the condensing engine needs relief valves, is that the vacuum in the exhaust line reduces the steam pressure in the cylinder to such a point that, after the central exhaust ports are closed, the steam which is trapped in the cylinder cannot be compressed to more than 75 or 80 per cent of the initial pressure. In case the vacuum should fail this compression pressure would exceed the initial pressure, hence automatic compression relief valves are used to reduce the compression.

### Unaflow Auxiliary Exhaust Valves

Where unaflow engines are designed for non-condensing operation the automatic compression relief valves are, as a rule, replaced by auxiliary exhaust valves located on the side of the cylinder at the end of the stroke. These exhaust valves are operated usually by the same sort of cam and mechanism as the steam valves, except that they are driven by a fixed eccentric instead of the governor.

The function of these auxiliary exhaust valves must not be confused with the ordinary type of exhaust valves, as they release only a small portion of the steam from the cylinder at a time when the pressure is practically zero. The main volume of the expanded steam is exhausted through the central exhaust ports, which are uncovered by the piston at 0.9 of its stroke, the purpose of the auxiliary valves being merely to delay the compression to such a point that the pressure in the cylinder at the end of compression stroke will be approximately 80 per cent of the initial pressure.

In the design of unaflow engines generally valves of either the piston type or of the poppet design have been used. In the following chapters on the methods of setting valves, more details will be given of the different types of valves which are used with unaflow engines now on the market.

## CHAPTER II

## DETAILS OF MODERN ENGINES

ASIDE from the particular types of valves used on engines the general points of interest in engine design are details such as the frame, cylinder, piston, cross-head and connecting rod. While changes in these parts have not been radical, certain definite trends have been noticeable.

For instance, the frame of the Corliss engine has experienced decided changes in shape in recent years. Formerly the girder frame was most commonly used. The

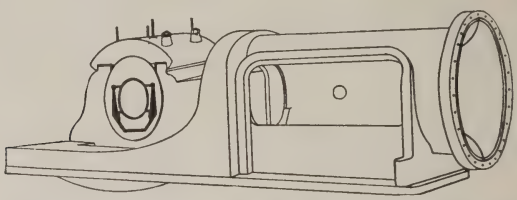


FIG. 9. HEAVY DUTY FRAME FOR A CORLISS ENGINE

girder frame took its name from the fact that the part of the frame between the main bearing and the cylinder did not rest on the foundation but acted as a girder supported by a stand or leg placed about the middle of its length. The cross-section of the girder frame between the guides and the main bearings was in the shape of the letter T to give greater stiffness for the weight of metal in it. The guides formed a part of the frame itself being either bored to a circular shape or planed to a V shape, hence this part of the frame was stiffened by the guides.

### Heavy Duty Frames

Girder frames have been largely replaced by the heavy duty types of frame the form of which is shown in Fig. 9. This frame is built in one piece from the cylinder to the main bearing and is box shaped to allow it to rest squarely on the foundation throughout its length but is cut away

on the outside from the guide towards the main bearing. The cylinder is bolted to the end of the frame and is supported independently. The guides are formed in the frame itself, and the frame is formed into a complete circle at both ends at the guides to give greater strength and stiffness. In some heavy duty frames the part forming the guides is made separate from the part containing the main bearing, being made in the shape of a barrel, and bolted to the rear section, and to the cylnider but not resting directly on the foundation.

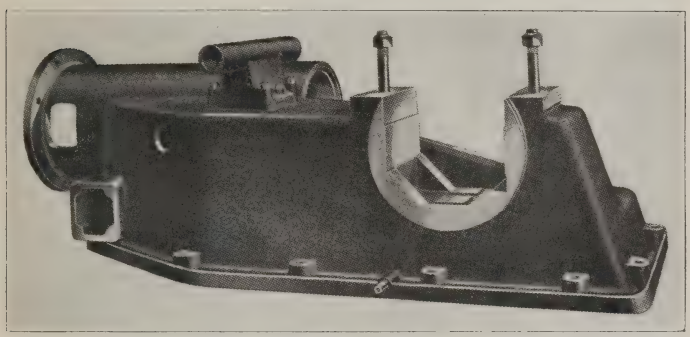


FIG. 10. HEAVY DUTY FRAME FOR A UNAFLOW ENGINE

Frames for unaflow engines have as a rule been developed as the enclosed type and made extra heavy. In Fig. 10 is shown a frame for a modern type of unaflow engine. The base of the frame extends the full length of the casting and an oil pan is furnished under the connecting rod and crank, cast integrally with the frame. The bottom edge of the frame has a bead forming an oil-catching rim.

It will be noted from Fig. 11 that the main bearings are provided with removable journals made of a bottom and two sides lined with babbitt metal. The bottom box is tongued and grooved into the frame and the quarter boxes are doweled to the bottom box to prevent side play. The quarter boxes are made extra high to eliminate the necessity of a top box, thereby air cooling the bearing.

There are practically no distinctive types of cylinders, the principal differences being in some details of design and construction. Some engine makers build cylinders

with the forward head cast solid with the cylinder but the general practice is to have it as an integral part of the frame.

Engines with valves placed transversely in the cylinders, such as Corliss engines, necessarily use cylinders of box section at the end.

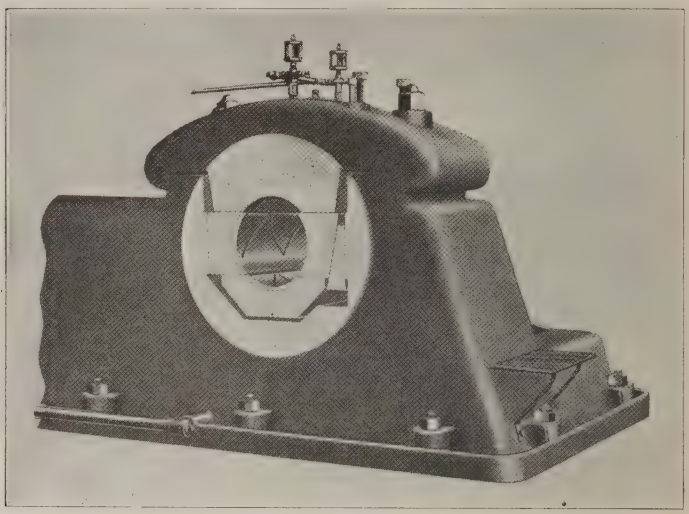


FIG. 11. TYPICAL ARRANGEMENT OF BEARING IN A HEAVY DUTY FRAME

In unaflow engines the cylinder, is quite simple in design without any complication except for the central exhaust ports and the exhaust belt.

### Cylinder Heads Used as Steam Jackets

In this type of engine the cylinder heads are separate castings and are provided with cored passages to provide inlet ports and steam jackets for the inner surface. The jacketing insures that the inlet end is as hot and dry as the entering steam so that the amount of steam condensed is reduced to a minimum. Fig. 12 is a view of a unaflow engine cylinder, giving an idea as to how the cylinder heads are bolted to the main part of the cylinder which contains the exhaust ports at the center.

It can be seen that the unaflow engine cylinder is, therefore, in all cases separate from the main part of the engine frame and must be bolted to the frame and supported by either an extension of that frame, or else by a separate pedestal.

### Types of Crossheads

Crossheads are of four general types: namely, locomotive, box, slipper, and H. The locomotive type is one of the most familiar forms of construction, for many types

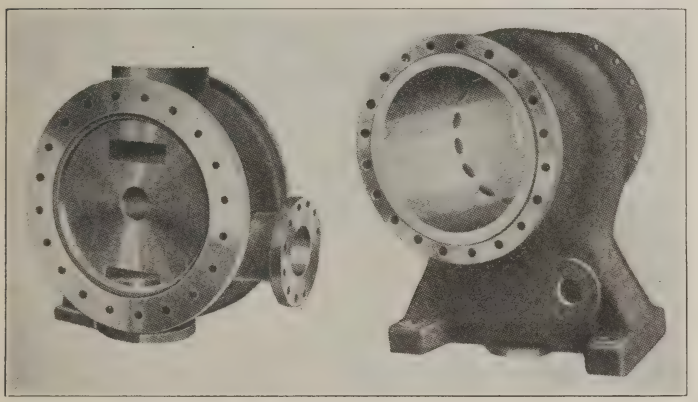


FIG. 12. CYLINDER AND CYLINDER HEAD OF A UNAFLOW ENGINE

of horizontal engines using box beds. This consists of a hollow U-shaped casting the sides of the U being square in section with the crosshead end cast integral with it. The wearing surfaces are faced with babbitt or some antifriction material and adjustments for wear are made in the guide.

Box type crossheads consist of a box head casting, open at one end and provided with adjustable shoes at the top and bottom. In some constructions, the shoes are tapped and are adjusted by moving them forward or backward by means of bolts fastened to the crosshead cheeks. Another form of construction employs a wedge between the shoe and crosshead, adjustment being made by screwing the wedge backward or forward.

The slipper-type crosshead consists of a U-shaped casting, attached to a slipper that travels beneath the crosshead guide. The crosshead pin being removable as in the box type.

With H type crossheads a hollow casting with shoes bolted to each side is sometimes used. The lower shoe is made adjustable by means of screws fastened to the body which force the body and shoe apart or allow them to

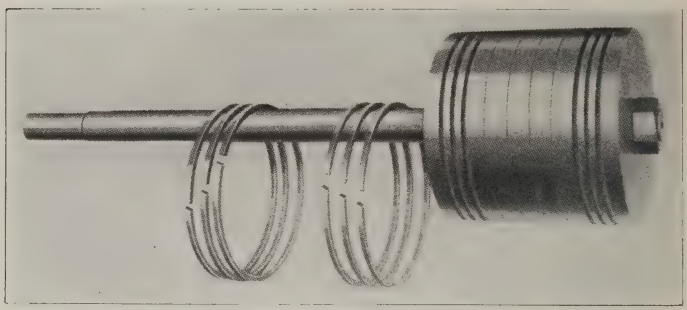


FIG. 13. ONE TYPE OF PISTON USED ON A UNAFLOW ENGINE

come together. In some crossheads of the box type shims are employed for adjustment.

### Four Types of Pistons Used

Steam engine pistons may be divided into four general classes: namely, solid, hollow, conical and built-up types. For small engines with cylinders less than 10 inches in diameter the solid cast-iron or steel piston is frequently used, the piston rod being inserted and secured by a nut. Several methods are in use for securing the piston rod, one common construction being to have the end of the rod that is inserted in the piston tapered, with or without a shoulder to bear against the side of the piston and secured with a single nut, the end being riveted over. In other forms the rod is made a forced fit through the piston and projects sufficiently to receive a nut.

In the outside of the piston are one or more rectangular grooves to receive the packing rings. These rings are turned eccentric from cast iron and cut through in one place in such a manner that the ends overlap. In Fig. 13

is shown a modern type of piston such as is used with a unaflow engine. This particular piston is of cast iron, with piston rings rough turned, split and ground to fit the cylinder bore.

Conical pistons are used in marine work and have been used in some cases for stationary engines. The advantage of this type is its extreme rigidity for its weight.

Built up pistons are largely used on engines of the horizontal type, to facilitate taking up wear which is greater with a heavy piston. The body is a spider with radiating arms to which the follower plate is bolted. A bull ring is placed around the spider and is supported by studs and adjusting nuts, and in turn supports the packing rings which are usually of sectional form held out by coil or flat springs.

### Types of Connecting Rods

There are three general types of connecting rods, the strap, solid end and marine, each of which has its advantages for various classes of engines. The strap-end type consists of a rod forging of iron or steel with a forged strap generally attached to the rod by two bolts with lock nuts. The brasses are flanged on both sides and slip into the strap. Numerous styles of adjustment for the brasses are in use, one of which consists of a taper key fixed by a set screw.

Liners are placed between the brasses and between the inner brass and the rod. As the brasses wear, liners are removed from between them and the wear taken up. This type of rod is especially adapted to engines the construction of which does not permit of the rod being removed sidewise, or with a box type of crosshead in which the crosshead pin is part of the head itself.

The connecting rod of the solid-end type has the end forged with the rod and the recess for the brasses is cut out by drilling holes around an outline and then finishing it on a shaper. The brasses are flanged on one side only, slip into the head, and are adjusted by wedges and bolts.

In the marine type the rod is enlarged at the end to carry one-half of the box and the other half is carried by a separate piece which is bolted on. Adjustment for wear

is made by liners between the halves, and for length by liners between the inside half of the box and the rod.

Any connecting rod may have a combination of these types, for example one marine end and one solid end.

In Fig. 14 is shown a connecting rod in which the crosshead end of the rod is forged solid and bored to receive cast-iron boxes mortised and rigidly held in place by lock screws. It is lined with babbitt and is provided with wedge adjustment. At the crank end it is fitted with the marine type crank box.

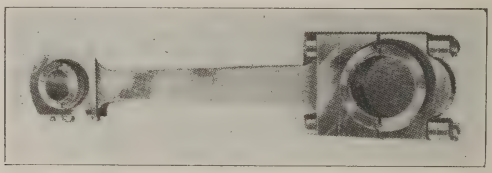


FIG. 14. CONNECTING ROD WITH SOLID AND MARINE ENDS

One difficulty with the strap-end type of connecting rod is that it is difficult to provide a strap sufficiently heavy to prevent springing under over load conditions. Light straps are liable to cause pounding.

## Flywheels

Flywheels are used to steady the speed against fluctuations, and to equalize the varying turning effort on the shaft by storing energy during the first part of the stroke, when the crank effort is greater than the resistance, and restoring it when the steam pressure decreases with expansion. On small engines flywheels are generally cast in one piece and forced onto the shaft by hydraulic pressure. To relieve stresses moderate sized flywheels of heavy section are usually provided with a split hub through which heavy bolts pass for clamping the wheels securely to the shaft.

For diameters too large for convenient handling or shipment, wheels are made in halves with bolts for the hub, the rim being held together by links set into recesses in the rim, or by bolts, or both. With this construction one-half of the wheel can be lowered into the wheel pit when erecting the engine, before the shaft is placed; then the upper half can be assembled on the shaft.

For large engines the weight of the wheel necessitates making it in sections, the sections of the rim being divided in a manner similar to that of the two part wheel, while at the hub end the spokes are bolted between two disks which are fastened on the shaft.

## How Crank Shafts Are Built

Shafts are made in numerous forms, the principal types being the following: Solid forged, solid forged center crank and built up shafts. The solid-forged, center-crank shaft is forged with a projection on one side near the center and cut out leaving a blank for the crank which is turned by placing the shaft in such a position that the axis of the crank pin is in line with the lathe center. Such a shaft is generally balanced by counter weights which are bolted on.

Built-up shafts are frequently employed in center-crank engines, the shaft being made in two pieces, which are pressed into disks and these disks connected by the crank pin pressed in, thus forming the crank.

In some cases disk cranks with the pin cast solid have been used. A common construction is a disk crank with the pin pressed into it. The cranks are balanced by making them extra heavy on the side opposite the crank pin, while the plain crank is frequently balanced by weights bolted on, and is known as a fantail crank.

Details described form the essential differences between types of engines as far as the mechanical construction is concerned. The main and important differences are in the types of valves which are used and the method of valve operation which is followed. For the operating engineer it is important that a thorough understanding of valve setting be obtained since the effect on the efficient utilization of steam due to proper valve setting is the most important part of engine operation. In the following chapters some of the details of setting valves of different types will be discussed in detail.

## CHAPTER III

## SETTING THE SLIDE VALVE

WHEN a slide valve is at the middle point of its travel, in which position the eccentric is vertically over the center of the engine shaft, the valve is in mid position. This position of the valve is used as a reference point, from which the parts of the valve and also its different positions are measured. The cross-section of a slide valve in its mid position is shown in Fig. 15. When it is in this

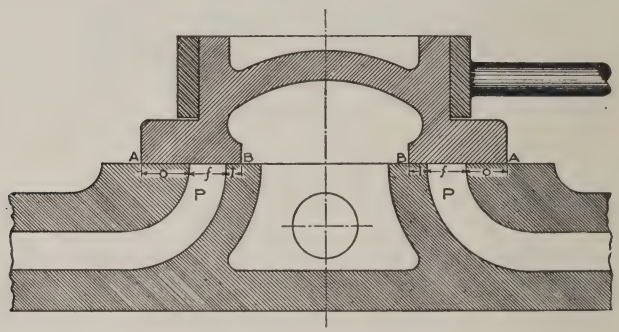



FIG. 15. MID POSITION OF A SLIDE VALVE

position, the length from the outer edge of a port to the outer edge of the valve is called the outside lap. This outside lap is shown by the dimensions O and O′. It is not necessary that the outside lap at one end of the valve be equal to that at the other end and in fact they are usually unequal, as will be explained later. The distance from the inside edge of a port to the inner edge of the valve is called the inside lap. The inside lap is shown by the portion I and I′. The inside laps of a valve are usually unequal, while the widths of the ports, or the distances f, are usually equal for both ends of the cylinder.

### Explanation of Lap

When steam is admitted past the outer edge of the valve, the outside lap is usually called the steam lap and the inside lap is the exhaust lap. When steam is admitted

past the inside of the valve and exhausted past the outer edge as is sometimes done, the inside lap becomes the steam lap and the outside lap is called the exhaust lap. The steam lap is usually much greater than the exhaust lap, hence a valve designed for outside admission will not distribute the steam properly if it is used for inside admission. Unless otherwise mentioned, the outside lap will be considered as the steam lap, as this is the more usual arrangement.

A valve that has steam lap will keep the ports closed against the admission of steam until the valve moves from

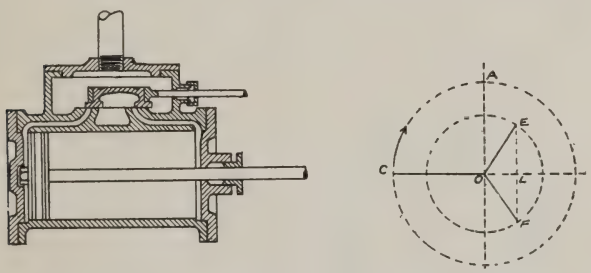



FIG. 16. VALVE SET FOR STEAM AND EXHAUST LAPS

its mid position a distance equal to the steam lap. The valve shown in Fig. 16 is an outside admission valve and it has moved to the right of its mid position a distance equal to the steam lap. In this position the valve is just on the point of admitting steam to the head end of the cylinder. If the valve now moves to the right, steam will be admitted to the cylinder and admission will continue until the valve goes to the extreme right hand position and then moves to the left and returns to the position shown in Fig. 16 when the port will be closed. The port will then remain closed, and the steam will expand until the valve moves far enough to the left to bring the inner edge of the valve in line with the inner edge of the port.

Further movement of the valve to the left, uncovers the port for exhaust, which continues until the valve, moving to the right on its return travel, reaches a position where the inner edge of the valve is again in line with the inner edge of the port. As the valve continues its movement to the right the port remains closed and the steam in the

cylinder is compressed. Compression continues until the valve, still moving towards the right, reaches a position in which the outer edge of the valve is in line with the outer edge of the port, when admission again occurs. It is thus seen that the purpose of having steam and exhaust laps is to permit the steam to be expanded and compressed.

In the above action the valve is set to admit steam to the cylinder just at the beginning of the stroke. If a valve is set in this way, there will be considerable drop in steam pressure during admission or "wire-drawing."

An inspection of the diagram at the right in Fig. 16 will show that, if the shaft rotates with a uniform

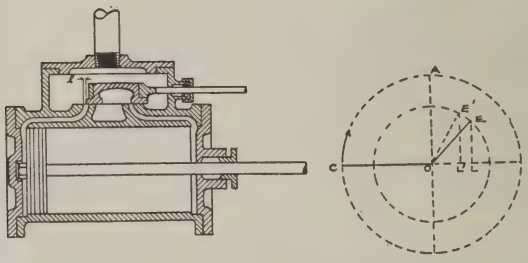


FIG. 17. SLIDE VALVE SET FOR LEAD

speed, the valve travels fastest when it reaches mid-position and the piston travels fastest when it reaches mid-stroke, the speed of each increasing during the first part of its motion and decreasing during the last part. This diagram also shows that at the beginning of the piston stroke the speed of the valve is decreasing as the speed of the piston is increasing. The result is that, if the valve is set to open just at the beginning of a stroke, steam cannot flow into the cylinder through the narrow opening fast enough to maintain full pressure behind the piston, hence the pressure in the cylinder drops.

In order to prevent excessive pressure drop during admission, the valve is set so as to open slightly before the end of the exhaust stroke, thus insuring enough port opening to allow free admission when the piston starts forward. The amount which the port is opened for admission when the piston is at the beginning of its stroke, is called the

"lead" of the valve. The amount of lead which a valve should have depends upon the size of the cylinder and the speed of the engine, being larger for high speed and large cylinders and smaller for slow speed and small cylinders.

### What Is Meant by Lead

A valve set with lead is shown in Fig. 17, the relative position of the crank and eccentric being shown in the diagram to the right of the figure. In this illustration, the piston is at the head end of its stroke and the valve is open an amount $l$ for the admission of steam to the head end, the distance $l$ in this case is the lead. It will be observed that, in the position shown, the valve has moved to the right of its mid-position, a distance equal to the steam lap plus the lead.

In the diagram at the right of Fig. 17, the crank OC is shown on dead center to correspond with the position of the piston. The line OE shows the position of the eccentric and the distance OL shows the displacement of the valve from its mid-position. If the valve was set without lead, the position of the eccentric would be OE′, the distance OL′ being equal to the steam lap. Since the distance OL is equal to the steam lap plus the lead, the distance L′L is equal to lead of the valve. It will be observed that when the valve has lead, the eccentric must be turned ahead on the shaft from the vertical far enough to displace the valve from its mid-position, a distance equal to the steam lap plus the lead, when the crank is on center. For an outside admission valve connected directly to the eccentric, the eccentric must be set so that it leads the crank.

### Angle of Advance

If the eccentric was in the position OA, Fig. 17, when the crank was on center, the valve would be in its mid-position, hence the eccentric must be moved forward through the angle AOE in order to displace the valve, from its mid-position a distance equal to the steam lap plus the lead. This makes the angle between the crank and the eccentric greater than 90 deg. by the angle AOE which is called the angle of advance. It is the angle in excess of 90 deg. between the crank and eccentric. The angle of advance is about 20 to 30 deg., but its amount will depend

upon the steam lap and the lead which is desirable to give the valve. The angle of advance is important in valve setting as will be shown later, since it is the only thing about the slide valve mechanism besides the length of the valve rod which can be adjusted.

Many valves, especially of the piston type, are designed to admit steam from the inside and exhaust past the outer edge of the valve. In this case the inside lap is the steam

TABLE 1. EFFECT OF MAKING ALTERATIONS TO EXISTING VALVES

| By Increasing The | Admission | Expansion | Exhaust | Compression |
|---|---|---|---|---|
| Outside Lap | Occurs Later Ceases earlier. | Occurs earlier. Continues longer | Remains unchanged | Begins as before |
| Inside Lap | Remains unchanged. | Begins as before. Continues longer. | Occurs later. Ceases earlier. | Begins sooner. Continues longer. |
| Angular Advance | Commences earlier. Period Unchanged. | Begins sooner. Period unchanged. | Commences earlier. Period unchanged. | Begins sooner. Period unchanged. |

lap and the outside lap is the exhaust lap. The eccentric follows the crank and the angle between crank and eccentric is 90 deg. less the angle of advance.

## Slide Valve Setting

In setting the slide valve two operations are involved, the first of which is determining the correct position of the valve on its rod and the second is fastening the eccentric in position for correct angular advance. To accomplish these results, the engine is first placed on its dead center and the eccentric temporarily fastened on the shaft, at approximately the place it is to be located, preferably ahead of its true position. Measure the lead of the valve; then turn the engine in the direction that it will run, until the other dead center is reached and again measure the lead. If there is any difference in the two amounts, of lead, the valve should be moved on the rod to equalize the difference.

The next operation is moving the eccentric on the shaft until the port is closed and then in the direction of rotation until the desired lead is obtained, finally securing the eccentric in position.

It is advisable to determine the effect of making alterations to existing valves, before attempting to change them, therefore, table I will be of value.

## Setting Piston Valves

For the piston valve it is necessary to work by measurements, since the valve is not accessible for direct observation. First, make a measuring rod, as shown in

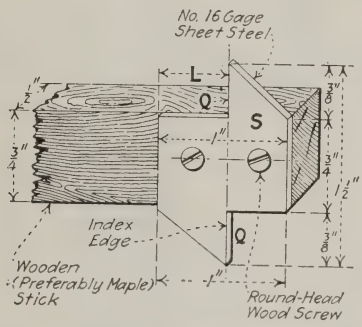



FIG. 18. MEASURING SLIDE FOR USE WITH PISTON VALVES

Fig. 18 for locating the steam ports in the valve chest. These steam port locations will, as is hereinafter described, be transferred to the steam port templet. The sheet steel head, S, may be of approximately the proportions as specified but, in any case, the dimension L should be at least $\frac{1}{16}$ in. less than the width of the engine steam ports. Two pieces of smooth clear pine, each about $\frac{1}{2}$ in. thick and about 1 in. wide will be required. Both should, at the start, be about the same length as the measuring rod. All faces and ends should be square and true.

Remove the valve chest cover and the valve stem stuffing box gland. Disconnect and remove the valve from the valve chest. Insert the measuring rod into the valve chest so that one of its index edges is against the further edge of the farthest steam port. With a knife blade, cut a corresponding line, A on the face of the rod exactly at the

level of the valve chest face. Similarly, locate on the measuring rod lines B, C and D, which respectively correspond to the other edges of the steam ports.

### Making a Piston Valve Templet

Now, lay one of the sticks, which was prepared as above, on the measuring rod. With a try square and knife blade transfer the lines from measuring rod to the ½ in. face of the stick. In the illustrations, the width of the sticks is shown exaggerated for clearness. Draw pencil "hatch" lines on those portions of the stick's face which do not

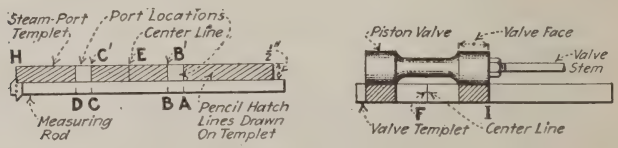



FIG. 19. LAYING OUT VALVE TEMPLETS

represent the ports. Draw, midway between C′ and B′ a knife-cut center line E, across the stick's face. This completes the steam-port templet.

Lay the piston valve, Fig. 19 on the 1-in. face of the other stick which was previously made. The left end of the valve should lie about ½ in. from the left end of the stick. Transfer to the ½-in. face of the stick lines representing the locations of the edges of the valve faces. Draw a center line F, midway between the two sets of lines which represent the valve edges. Hatch, with pencil lines, the portions of the stick's face which represent metal.

The valve templet must be of a certain length so that, when in use (Fig. 20) for valve setting, it will reproduce accurately the events which are occuring in the steam chest. When in use, the lower end of the valve templet rests on the upper end of the valve, while the valve is shifted vertically to different positions. The valve templet slides alongside the steam-port templet. To determine the proper length of the valve templet proceed thus: Lay the steam-port templet against the valve templet (as shown in the right hand view of Fig. 20), with their two center lines F and E exactly in line. Now, the distance EH on

the steam-valve templet equals the actual distance from the horizontal center line between the steam ports to the top face of the steam chest. Also, the distance FI on the valve templet equals (See Figs. 19 and 20) the actual distance between the horizontal center line of the valve and either end face of the valve. Hence, it follows that IJ is the distance which the top face of the piston valve must

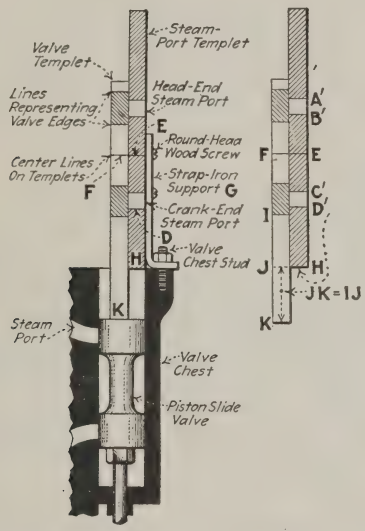



FIG. 20. VALVE TEMPLETS METHOD APPLIED TO A VERTICAL ENGINE

lie below the top face of the valve chest when the valve is vertically central in the valve chest in relation to the ports. Now lay off on the valve templet below J a distance JK, which is equal to IJ. Cut the templet off square at K and it will be complete and of correct length.

It is necessary, as indicated in Fig 20, to arrange the valve templet on the engine valve chest. This particular arrangement is for a vertical engine but a similar scheme may be used for horizontal engine. The main point to keep in mind is that the port templet must be fixed in some way so that it will not accidentally be moved.

The method shown in Fig. 20 is carried out as follows: Bend a piece of strap iron to form a support, G, for the

steam-port templet. Drill the short leg of the support to accommodate one of the valve-chest studs and drill the long leg to take three round-head wood screws. Replace and reconnect the valve in the chest. Secure the steam-port templet to the valve chest, with the "H" end of the steam-port templet exactly on a horizontal line with the top face of the steam chest. Now place the valve templet alongside of the steam-port templet with the lower end, K, of the valve templet resting on the upper face of the valve. The end K should always, when the templets are in use, rest on the upper end of the valve. Now, if the templets have been accurately made, they will visibly reproduce, outside of the steam chest, the invisible events which are occurring within it.

To use the templets for valve setting, it is merely necessary to measure the valve events which occur from the templets—instead of measuring them directly from the actual valve and ports. In other words the procedure is exactly the same as for a D valve. After the valve has once been set correctly, it may be desirable to label and retain the templets for future use. But, if the proper trammel is made and center-punch reference marks are spotted on the valve stem, the use of the templet for resetting will be unnecessary.

### Setting Shaft-Governed Valves

Most engines are rated about ¼ cut-off, hence when setting a valve which is driven by a shifting eccentric, the governor should be blocked out to a position that will give that cut off. The operation is then the same as that for the D valve with fixed eccentric, allowing, of course, for the reversal of motion if a reversing rocker is used between eccentric and valve. After the valve is set, the engine should be turned over and the crosshead position noted for cut off at each end. Sometimes it is desirable to adjust for somewhat greater lead for the crank end in order to bring the cut off more nearly equal but the head-end lead should never be cut down so as to show late on the diagram and the lead should never be so large as to cause racing at light loads.

If the governor is so made or located that it can not be blocked out, the setting may be made with the governor

at the innermost position as the division of lead between the ends is not greatly altered by the change in position of the governor and the exact division of lead for best action can be determined by the indicator diagrams.

If the governor turns the engine around the shaft to alter the lead as in some of the old time motions, the valve is set the same as the D valve with governor in innermost position.

### Setting Riding Cut-off Valves

To set the main valve of an engine with a riding cut-off valve proceed as with the common D valve by equalizing

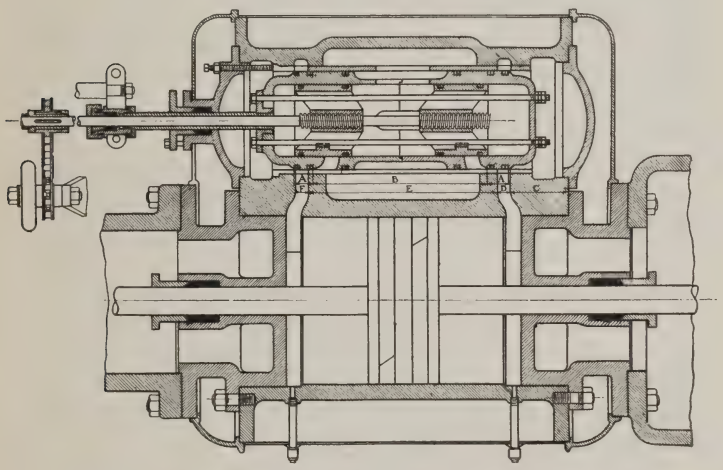



FIG. 21. SETTING MARKS FOR MEYER RIDING CUT-OFF VALVE

the lead at the ends so that the valve has about 1/64 in. lead at each end. The main eccentric is then made fast to the shaft, and the setting of the cut-off proceeded with.

Different portions of the stroke are laid out along the crosshead slide and from each end of the stroke. With the crosshead in the position at which it is desired that cut-off should take place, the cut-off valve is adjusted so that it just closes the port in the main valve, the governor being blocked out to running position. The engine is then moved to the corresponding position in the return stroke when the cut-off valve should just close the port in the

main valve. If the cut-off valve does not close the port in the main valve, the length of the valve rod should be changed and the cut-off is simply shifted until equal cut-off is obtained at both ends.

In steam driven compressors built by the Chicago Pneumatic Tool Co. the Meyer cut-off valve is used on duplex compressors of 12-in. stroke and above.

In this valve as shown in Fig. 21, the cut-off is adjustable, allowing the compressor to operate at the most economical cut-off for the conditions existing. This is effected by means of an adjusting hand wheel which serves to revolve the right and left-hand-threaded valve stem thus drawing the cut-off valves together or spreading them apart. A range of from one-quarter to three-quarters cut-off is available and adjustment can be made while the machine is operating. An index block and scale indicate the points of cut-off.

The valve gear consists of double eccentrics, cast integral so that the position of the cut-off eccentric is fixed, once the main valve eccentric is set.

### Instructions for Setting Piston Riding Cutoff

Instructions for setting this valve are as follows: Draw the cut-off valves as close together as possible by turning the hand wheel. Set the main valve in the manner described for the plain D slide valve; the main valve eccentric should lead the crank by about 112 deg.

Set the crank on head end dead center and scribe a vertical line on the crosshead and crosshead guide. Then set the crank on crank end center scribing a vertical line on the crosshead guide in extension of the line on the crosshead. Now divide the space between the two lines on the crosshead guide into four equal parts scribing a line to indicate each division. Set the crosshead at half stroke and adjust the cut-off valve until it is just cutting off the port in the main valve. Move crosshead to the corresponding position for the other stroke, and the other cut-off valve should just close the port of the main valve. If it does not just close the port, the valve should be moved along on the stem to the correct position.

These valves should be set to cut off alike at some predetermined point, for the valves may be set to cut off alike

at any given position but they will not cut off exactly alike for any other position.

The cut-off piston valves shown in the illustration are set entirely by tramming, as for a plain piston valve. On the main steam valve rod and the cut-off valve rod will be found shop tram marks with figures, indicating the distance between them, stamped on the rod. When the valve rods are set so that the marks on them are apart the distance stamped on the main valve rod, the cut-off valves are centered in the main valve.

Remove the main valve from the chest and determine accurately the distances A, B, C, D, and E. Replace the valve and connect up the valve gear. Set the main valve eccentric approximately 74 deg. behind the crank. Then with crank on head end center adjust valve stem until the distance from the face of the chest to exhaust ring equals (C+D—A). Place crank on crank end center and, using same reference points as before, check for distance (C+D+E) — (A+B). In case the distances do not agree, take up half of the difference on the valve stem and the other half by moving the eccentric. Continue in this manner until the lead at both ends is equal.

The index block will be correct as it is correctly adjusted before leaving the factory.

The method of setting the valve by allowing steam to blow through the cylinder with cut-off at various points should be used, and where possible the cylinders should be indicated.

## CHAPTER IV

## CORLISS VALVE SETTING

WHEN the various parts of a Corliss valve gear are in proper adjustment, the reach rod and the eccentric rod should be of such length that the rocker arm and the wrist plate will be plumb when the eccentric is vertical. Manufacturers of Corliss engines usually place a mark A, such as shown in Fig. 22, on the hub of the wrist plate

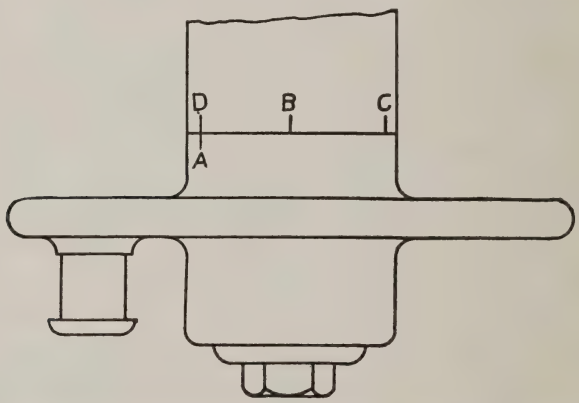



FIG. 22. MARKING USUALLY FOUND ON WRIST PLATE OF CORLISS VALVE GEAR

and three marks D, B and C on the wrist plate stud. When A coincides with B the wrist plate is in its central position and in this position the rocker arm and the eccentric should be vertical. When A coincides with B the wrist plate is at one extreme of its travel and the eccentric is on its dead center and when A coincides with C the wrist plate is at the other extreme of its travel, and the eccentric is on its other dead center.

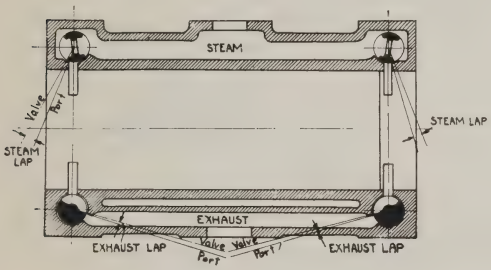
If the marks A, B, C and D are not on the wrist plate and stud, they should be placed on with a chisel, A and B being marked when the eccentric is vertical and the rocker arm and wrist plate are plumb, and D and C being marked opposite A when the eccentric is on its dead center.

## Setting Single Port Corliss Valve

In order to show the method to follow in setting valves of the Corliss type an example will be taken of a valve of single port type, Fig. 23, with single eccentric.

First, turn the engine over and see that the wrist plate travels equal distances each side of the central position. If not, make it do so by adjusting the eccentric rod when the gear is in one of the extreme positions as indicated by the marks on the hub.

After this is done, the work of setting the valves proceeds. The releasing mechanism for a valve of this type is shown in Fig. 6, Chapter I. Raise the hook rod and place




LAP OF VALVES

| DIA. OF CYLINDER | STEAM LAP | EXHAUST LAP |
|---|---|---|
| 12" | 3/16" | 1/32" |
| 14" | 1/4" | 1/16" |
| 16" | " | " |
| 18" | " | " |
| 20" | " | " |
| 22" | 5/16 | 3/32" |
| 24" | " | " |
| 26" | " | " |
| 28" | " | " |
| 30" | " | " |
| 32" | 3/8" | 1/8" |

FIG. 23. SINGLE-PORTED CORLISS VALVES

the wrist plate in central position. Then remove the valve covers at the back side of the cylinder and a chisel mark will be found on the end of each valve. This mark is in line with the cutting edge of the valve and another chisel mark on the end of the counter bore, is in line with the edge of the cylinder port. With the hook on the steam arm engaging with the block on the dash-pot arm, the valve should be placed as shown in the sectional view of the cylinder in Fig. 23, having the steam lap and exhaust lap corresponding to the amount given in the table of Fig. 23 for the size of cylinder. The rods connecting the wrist-plate with the valve arms have right hand threads on one end and left hand threads on the other so that the length of the connection can be made greater or less by turning the rod one way or the other. In this way the cutting edge of each valve can be placed in the proper relation to the corresponding port edge of the cylinder as given by the table.

When valves are set the engine crank should be placed on one of the dead centers, say the one nearest the cylinder. The piston is then at the end of the stroke towards the head end of the cylinder. Move the wrist plate until the hook rod drops into place on the driving pin. Then examine the steam valve on the head end of the cylinder. The mark on the valve should be $\frac{1}{16}$ in. nearer the center of the cylinder than the line on the cylinder corresponding to the edge of the port, this $\frac{1}{16}$ in. opening being called steam lead. If it is much more or less than $\frac{1}{16}$ in., loosen

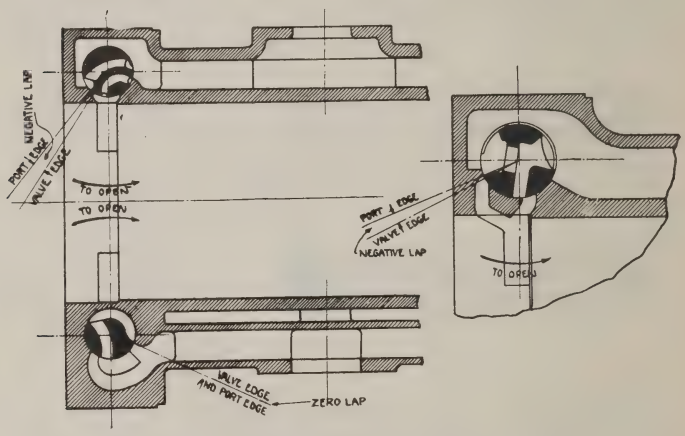



FIG. 24. DOUBLE-PORTED CORLISS VALVE

the set screws in the eccentric and move the eccentric on the shaft one way or the other until the valve is in the correct lead position. When the correct position of the eccentric is found, mark the eccentric and shaft to correspond in such a way that it can be detected later, should the eccentric slip from its correct position. Then fix the eccentric on the shaft and replace the back valve covers and the engine should be ready to operate.

### Setting Double-Port Corliss Valves

For setting valves of Corliss engines with double eccentrics and double-ported valves as shown in Fig. 24, the Bates Machine Co. gives the following instructions:

On the hub of the wrist plate, or of the steam valve crank where no steam wrist plate is used, and on the wrist-

plate base, or steam bonnet, will be found the chisel marks referred to at the beginning of the chapter.

If the back valve-covers of the cylinder be removed, chisel marks will be found on the ends of the valves, and on the ends of the valve chamber counter bores, as for the single ported engine.

Steam valves are set by the same process as for the single-ported, single eccentric engine, but given a negative lap, about $\frac{5}{16}$ in. for a cylinder 18 in. diameter and steam lead about $\frac{1}{16}$ in.

### Exhaust Valve Setting

To set the exhaust valves, proceed in the same manner by raising the hook rod and placing the wrist plate, (for double eccentric engines, use the exhaust wrist plate), in the central position. The valve edge and port edge of each exhaust valve should then be brought in line with each other by adjustment of the valve rod connecting the wrist plate and exhaust arm, giving the valves zero lap in the central position. This is the only adjustment for a single eccentric engine.

For a double eccentric engine, now turn the engine over until the cross head is about 4 in. from the end of the stroke, say towards the head end. The exhaust eccentric should then be moved on the shaft, until the exhaust valve at the head end of the cylinder has its cutting edge in line with the port edge of the cylinder. This will give the proper compression for a medium sized cylinder, 22 to 24 in. diameter. For a smaller cylinder it will be better to place the cross head about 3½ in. from the end of the stroke and for a larger cylinder about 4½ in.

Tighten the set screws in the eccentric, also nuts which have been loosened in making adjustments; replace the back valve-covers and then the engine should be ready for operation.

Steam valves on engines with double eccentrics are given negative lap in order to give a later cut-off where the load demands it. Where negative lap is used, it is necessary that the governor knock-off cams should be placed so that the dash-pot closes the valve at every stroke, otherwise there would be live steam on both sides of the piston at one point in every stroke.

## Adjustment of Valve Gear

During the course of the valve setting work, it is well to note the clearance around the catch block. It is important to adjust the length of the dash-pot rods properly, because, if they are made too short, the valves will not hook on and, if they are too long, the valve stem is liable to be bent or the steam brackets broken or both.

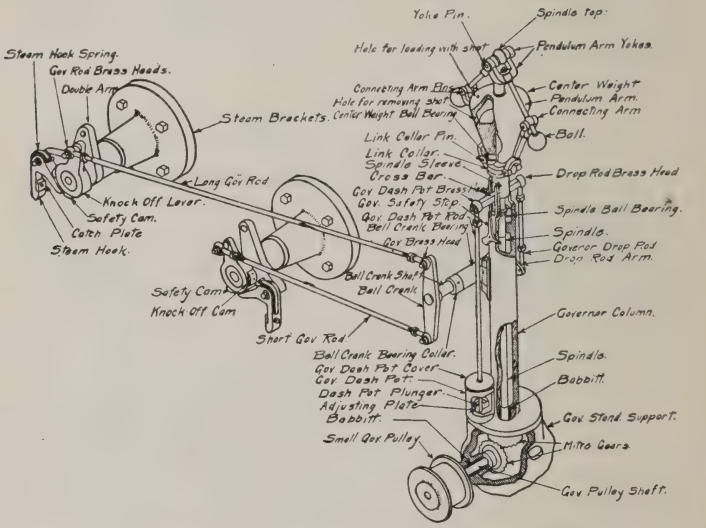



FIG. 25. METHOD OF HOOKING UP A GOVERNOR WITH CORLISS VALVE GEAR

The governor and governor rods should next be adjusted if they require it. Figure 25 shows a common form of Corliss engine governor with its connection to the valves, parts of the governor being cut away to show its construction. As shown here the parts of the governor are in the position they will occupy when the engine is running at normal speed. If the speed rises about normal, centrifugal force throws the governor balls farther from the center. This raises the cross bar, carrying with it the drop rod arm, and throws the knock-off lever on the valve stem so that the knock-off cams strike the steam hooks earlier thus causing an earlier cut-off. If the speed falls below normal, the knock-off cams are moved in the opposite direction and cut-off occurs later.

If the belt which drives the governor should break, the cross bar would drop to its lowest position and this would make cut-off come at the latest possible point in the stroke, or the steam hooks would not be disengaged at all so that the cylinder would take steam for the entire stroke, which would cause the engine to run away.

In order to prevent that possibility, safety cams are put on the knock-off lever. When the governor falls to its lowest position, the governor knock-off levers are thrown around far enough to bring the safety cams under the steam hooks thus preventing the admission of any steam to the cylinder. If the safety cams are allowed to come into action as described above, the engine cannot be started after it is shut down until the governor is raised high enough to prevent the safety cams from coming in contact with the hooks. It would be a nuisance to have to raise the governor every time the engine is started so a safety device is placed on the governor to prevent it from falling to its lowest position and bringing the safety cams into action when the engine is shut down by hand.

### Cut-offs Important in Multi-Cylinder Engines

Setting the valves on a compound or triple expansion engine of the Corliss type is precisely the same as for a single engine except that the adjustment of cut-offs in the various cylinders is largely a matter of "cut and try" until best results are obtained. This is usually considered to be at points where an equal load is carried by each of the cylinders.

An increase of cut-off in the high pressure cylinder, while the initial steam pressure and the cut-offs of the intermediate and low-pressure cylinders remain as before, results in an increase of the pressure in the first and second receivers an increase in effective pressure in all three cylinders and consequently results in an increase in horsepower of the engine. Conversely an early high-pressure cut-off without change of the other cut-offs and initial steam pressure causes a decrease in receiver pressures, effective pressures and horsepower.

Lowering the initial steam pressure in the high-pressure cylinder without change in cut-off results in lower receiver pressures, lower effective pressures and lower horsepower.

Conversely, if, under the same conditions, the initial steam pressure is raised, the receiver pressures, the mean effective pressures and the horsepower will be increased.

Other conditions remaining the same, if the intermediate cylinder cut-off is made later, the pressure in the receiver and the intermediate cylinder is less and the drop from the high-pressure cylinder increases, whereby the power developed in the high-pressure cylinder, owing to the increase in the effective pressure, is increased. At the same time the mean effective pressures in the intermediate and low-pressure cylinders decrease, hence the horsepower there developed will be decreased. The converse of this is also true.

### Effect of Change in Low Pressure Cut-off

Again, suppose that other conditions remaining the same the low-pressure cut-off is made later; then the pressure in the second receiver will be lower the mean effective pressure in the low-pressure cylinder, hence the horsepower there developed, will decrease. At the same time, the mean effective pressure in the intermediate cylinder increases, hence the horsepower there developed will increase but no change will take place in the high-pressure cylinder.

If, under the same conditions, the low-pressure cut-off is made earlier, the horsepower developed in the low-pressure cylinder will be increased, that of the intermediate cylinder will be decreased and that of the high-pressure cylinder will remain unchanged.

### Points to Remember in Setting Corliss Valves

In general the setting of Corliss valves may be summarized as follows:

1. Remove the steam and exhaust bonnets and upon the end of each valve will be found a mark corresponding to the opening edge of the port. The direction for opening the valve can be determined by working the wrist plate by hand.

2. Examine the wrist plate hub and bracket. Upon the bracket will be found a mark corresponding to the central position of the wrist plate and two other marks locating the extreme travel of the wrist plate in either direction of motion.

3. See that the rocker arm travels equal distances each side of the vertical position. To do this loosen the eccentric and rotate it slowly about the shaft. Then with a plumb bob and scale, measure the distance the rocker arm travels each side of its central position, and adjust the eccentric rod, to bring the distances equal.

4. Rotate the eccentric about the shaft and see that the wrist-plate travels equal distances each side of its central position as shown by the travel marks. If it does not, adjust the length of the reach rod to bring them equal.

5. Block the wrist-plate in its central position, then pull up the dash-pot rods until the hook pins engage with the steam hooks. Adjust the length of the steam and exhaust radius rods until the valves have the proper amount of lap as determined by size and speed of engine table.

6. Throw the wrist plate with the starting bar, first to one, then to the other extreme position and adjust carefully the length of the dash-pot rods so that the steam hooks will latch with the hook pins when the wrist plate is at its extreme travel, allowing $\frac{1}{32}$ in. for clearance.

7. Place the engine on dead center and see that the reach rod is fastened to the wrist-plate. The eccentric should then be turned in the direction that the engine is to run until the proper amount of lead is secured and the eccentric is then fastened to the shaft. Place the engine on the opposite dead center and measure the lead. If it is not the same, make it the same by adjusting the length of the steam radius rods.

8. Block the governor up half way in the slot and fasten the reach rod lever at right angles to a line drawn half way between the two rods. Adjust the length of the reach rods until the knock-off arms stand vertical; with governor in this position, turn the engine over until cut-off occurs and measure carefully the distance the crosshead has traveled; place the engine so that the crosshead will be the same distance on the other stroke and adjust the length of the reach rod until the cut-off will just occur.

9. Drop the governor to its lowest position and see that the safety blocks on the knock-off cams are adjusted so as to prevent the steam hooks from latching with the hook pins.

## CHAPTER V

## FOUR-VALVE ENGINES

AS MENTIONED in the first chapter, the four-valve principle has been applied to engines using different types of valves. One development of the four-valve type has been the building of a valve gear similar to the Corliss

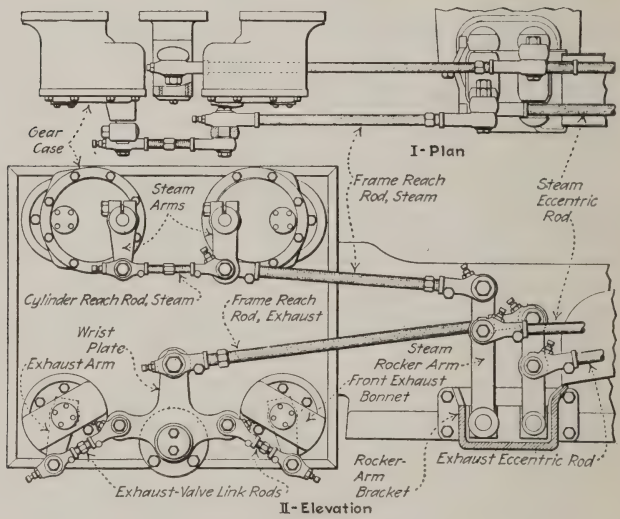



FIG. 26. NON-RELEASING TYPE OF CORLISS VALVE GEAR USED WITH BALL ENGINE

type but different in that no releasing mechanism is used. Engines of the four-valve type have also been fitted with grid-iron valves and with poppet valves.

One engine of the non-releasing Corliss type is the Ball, the valve gear of which is shown in Fig. 26. In setting the valves for this engine, the eccentric rod is adjusted so that the rocker arm travels equal distances on each side of the vertical position. The eccentric is then blocked up with the governor weight arm in its extreme outer position. In this position the center of the eccentric is in line with the centers of the suspension pin and of the shaft. Next the

engine is turned over until the steam valve at the crank end, moves as far towards opening as it will. If the valve does not come within $\frac{1}{32}$ to $\frac{1}{16}$ in. of uncovering the port, the reach rod connecting the rocker arm to the steam arm should be adjusted until the valve is in the position stated.

### Setting for Lap

When the engine is turned over until the head-end valve is moved towards its open position, the lap at the end of the valve travel should be $\frac{1}{16}$ to $\frac{1}{32}$ in. If it is not, the cylinder reach rod which connects the two steam arms should be adjusted. If this is done, the engine will not take steam when the speed throws the governor weight to its extreme position. An indicator is necessary to adjust the point of cut-off accurately for the two ends. The cut-off should be adjusted with the indicator so that it is practically the same at both ends. As there is considerable wire drawing at no load, this should not be eliminated. The pressure before cut-off should be about half the pressure at the throttle.

In setting the exhaust valve, the link connecting the two exhaust valve arms should be equal in length to the distance between the valve centers, for cylinder diameter of less than 19 in. Where the cylinder is more than 19 in. an exhaust wrist-plate is used and the exhaust valve link should be adjusted so that, when the wrist-plate is turned to bring the wrist-plate pin and the two link pins in a straight line, the exhaust valves should cover the ports with equal lap on both edges of the ports.

### Exhaust Valves Should Have Equal Opening

When the engine is turned over, the two exhaust valves should open equally. If not, adjust the length of the valve rod until both port openings are equal. The exhaust eccentric on the shaft is now moved so as to cause compression to begin at the desired point. This should be such that the compression pressure will rise to about half the throttle pressure. Head-end compression should be a little greater than crank-end. The correct amount is the least compression with which the engine will run smoothly.

## Fitchburg Valve Gear

To set the valves of the Fitchburg engine (Fig. 27), first adjust all rods and connections so that the several parts will travel equally on both sides of the center in a complete revolution of the engine. As the engine has two eccentrics, one for the steam valve and one for the exhaust valve they should be set separately. Ignoring for the present the exhaust valves, place the latch of the steam valves in the center of the spiral block and clamp the hook by its lever, adjusting the movement of the wrist cranks by the

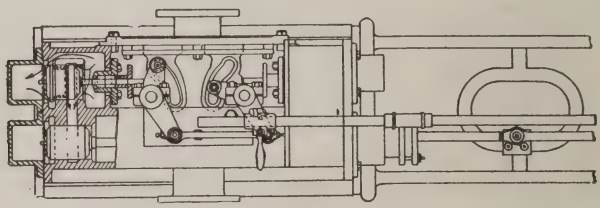


FIG. 27. FITCHBURG VALVE GEAR

right and left connection as provided. Set the engine exactly on the dead center and move the small rod attached to the head valve in or out of its cam until the port is opened the proper lead, which is usually about $\frac{1}{16}$ in. and tighten the set screws in the neck of the rod. Roll the engine on the other center and proceed as before.

To set the exhaust valve, adjust for equal travel as usual and set the eccentric on the shaft so that the exhaust valve for each end will close the port when the piston is about $\frac{1}{8}$ of the stroke from the end. It is best to spot all set screws to prevent slipping.

## Setting Valves for Lentz Engine

In the Erie City Lentz Engine the valves used are of the poppet type driven by eccentrics mounted on a lay shaft. These valves are of the double-seated balanced type.

In Fig. 28 is shown the arrangement of the valve gear for this type of engine. An admission valve eccentric is used which has an oblong slot in it to permit side travel so that the action of the governor will change the point of cutoff. The exhaust valve eccentrics are fixed in definite

position but may be advanced or retarded to control the point of release and the amount of compression.

In order to set the steam valve, the lay shaft is turned until the eccentric rod of the valve is at right angles with

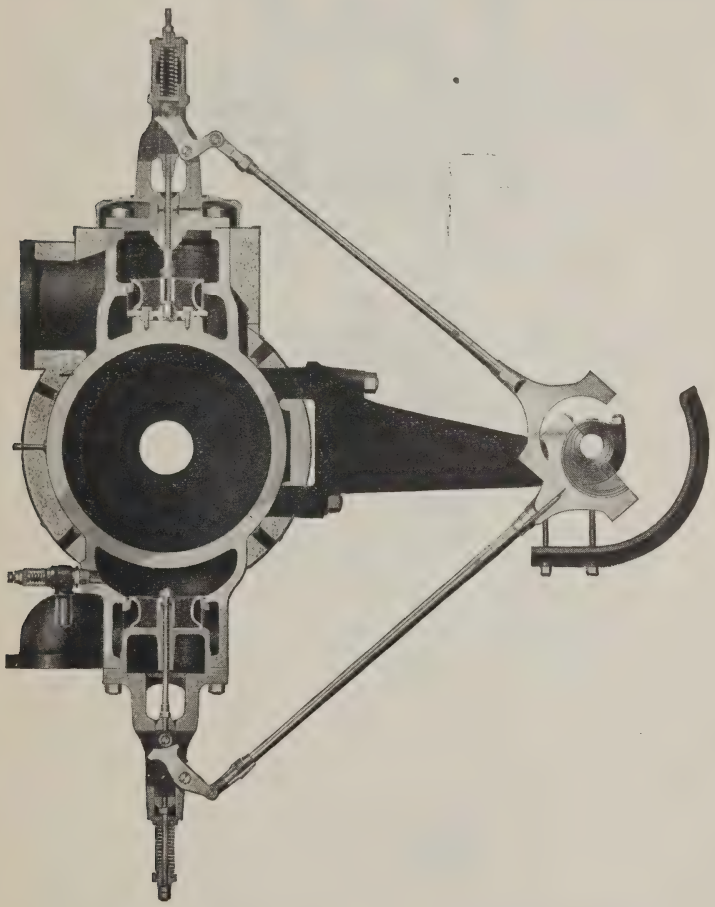


FIG. 28. VALVE GEAR OF ERIE CITY LENTZ ENGINE

the driving block which is linked to the governor. If the governor is now opened and closed from maximum to minimum positions, the steam cam lever should show but a slight movement. This position of the eccentric is the one which it assumes when the steam valve is to open and

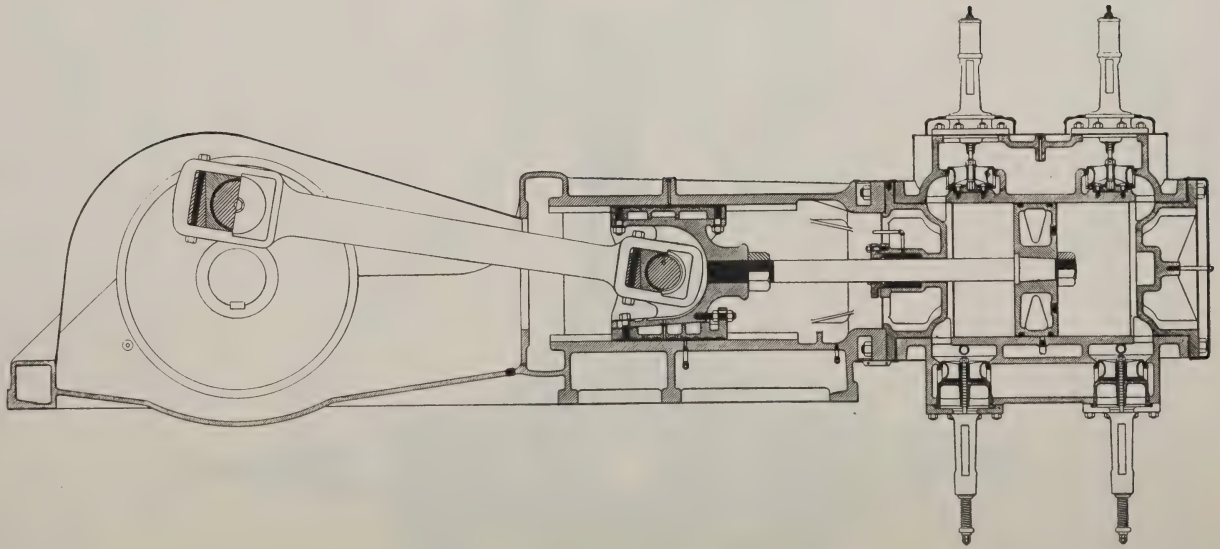


FIG. 29. POPPET VALVES ARE DRIVEN BY A LAY SHAFT IN LENTZ ENGINE

the valve stem or spindle should be adjusted by screwing in or out of its upper end so that the roller just touches the cam, and so that the movement of the eccentric raises the valve. This is the position of the valve with the engine on dead center.

### Timing the Valves

Timing of the entire valve gear is accomplished by shifting the bevel gear driving the lay shaft, one or more teeth. On the latest type engine, however, this is more conveniently accomplished by removing the bolts in the coupling flange on the lay shaft, located between the governor section and the gear section and moving the governor section the desired distance and in the desired direction, then inserting the bolts in the flange in the new position.

Shifting the steam eccentric ahead causes the lead to be greater and cutoff earlier. Shortening the eccentric rod will likewise increase the lead and give a later cutoff. The adjustment of the exhaust valve is made by shifting the eccentric ahead to get earlier release and compression. Shortening the rod will give earlier release and later compression.

These valves are tram marked at the factory with a punch mark on the valve stem and on the roller guide or crosshead. These marks are 2 in. apart. In case of removal and replacement of the valve, the stem length may be made as originally set by tramming this distance.

## CHAPTER VI

## SETTING AMES, CHUSE AND HARRISBURG VALVES

IN THE Ames unaflow engine, steam is admitted to the cylinder by a double beat poppet valve which is lifted by a roller in a square section sliding bar, when it comes in contact with the lifting cam. This cam is carried in a

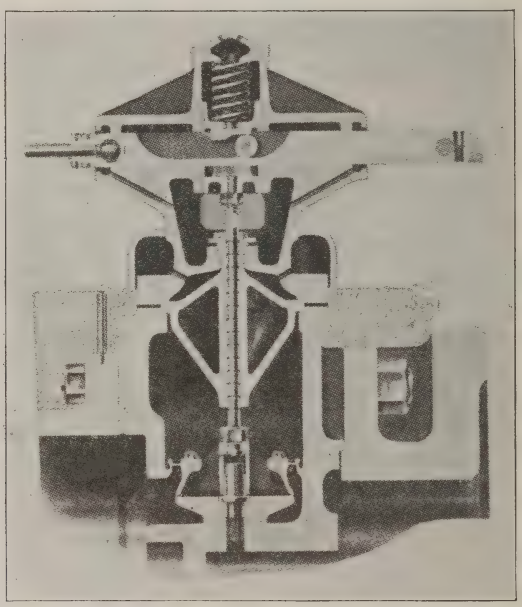


FIG. 30. SECTION THROUGH BONNET AND VALVE OF AMES ENGINE

cylindrical bronze cross head attached to the valve stem and the valve is closed by the coil spring on the top of this crosshead, the top of the spring bearing against the bonnet cap. In Fig. 30 is shown a section through the bonnet and valve which is used for steam admission. The exhaust as with all unaflow engines is through a center belt of ports.

When the engine is built for non-condensing service the piston has concave heads. This provides enough clearance volume to reduce the compression pressure to a reasonable amount.

### Protection Against Loss of Vacuum

For condensing operation the piston has straight ends and the clearance is made as small as possible. In order to protect the engine, if the vacuum should be lost, an automatic by-pass valve is used such as is shown in Fig. 31.

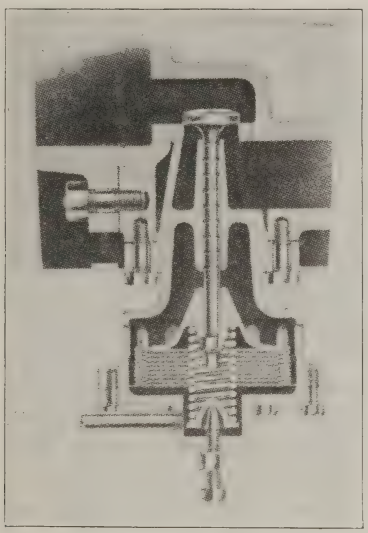


FIG. 31. BY-PASS VALVE PROTECTS THE ENGINE AGAINST HIGH COMPRESSION

These valves are controlled by the condition existing in the exhaust belt of the engine. They operate only with loss or restoration of vacuum and do not operate with each stroke of the engine. The small pipe is connected with the exhaust belt or exhaust pipe of the engine, thus communicating the conditions in the exhaust belt to the sylphon which is attached to the valve stem.

By the action of the vacuum the sylphon is collapsed, the coil spring compressed and the valve held firmly to the seat, which reduces the clearance in order to secure proper

compression for condensing service. If the vacuum is partially or totally lost the spring will open the valve which connects a clearance pocket in the cylinder head with the clearance in the cylinder thus increasing the total clearance volume and preventing undue compression during non-condensing operation. When the vacuum is again restored, the valve closes as above described.

It is possible to change the tension of the spring by adjusting screws, so that the point at which the valve opens and closes can be varied to a reasonable extent.

### Assembly of the Ames Valve Gear

Assembly of the valve gear is made on the basis of tram marks on the rods and rod heads which have been marked at the factory. These marks are stamped upon the rods after the valves have been set and before the engine is dismantled on the testing floor. If the engine, for any reason, has not been tested before shipment, the rods will not be marked, in which case the eccentric rod should first be connected to the rocker lever and so adjusted that the rocker lever over the frame travels equal distances either side of the vertical center line.

First adjust the valve stem so that there will be about 0.002 in. space between the flat part of the cams and the roller in the roller rods. This space is conveniently measured by using a thickness gage through the peep hole opening in the side of the bonnet. This space of 0.002 in. will be slightly increased as the valve stem expands when subjected to the steam temperature and should be about 0.003 in. when the engine is in operation.

With the valve stems adjusted as above, place the rod over the frame in position as shown in Fig. 32, turn the engine to its crank end dead center and adjust this reach rod so that the roller in the crank end roller rod just touches the cam. Then with the engine on its head end dead center, adjust the ball rod over the center so that the roller in the head and roller rod will just touch the cam or about the same as the crank end.

This is in the nature of a preliminary setting, only, and further adjustments will be necessary after the engine is in operation. In the illustration previously referred to, the controlled compression type of engine is shown. This

type of engine is used where it is desired to exhaust against back pressure of from 2 to 15 lb., where steam is required for low-pressure heating, drying or other purposes.

### Controlled Compression

In this case, secondary exhaust ports and valves are located directly at the ends of the cylinder so that the final exhaust closure is not controlled by the piston covering the

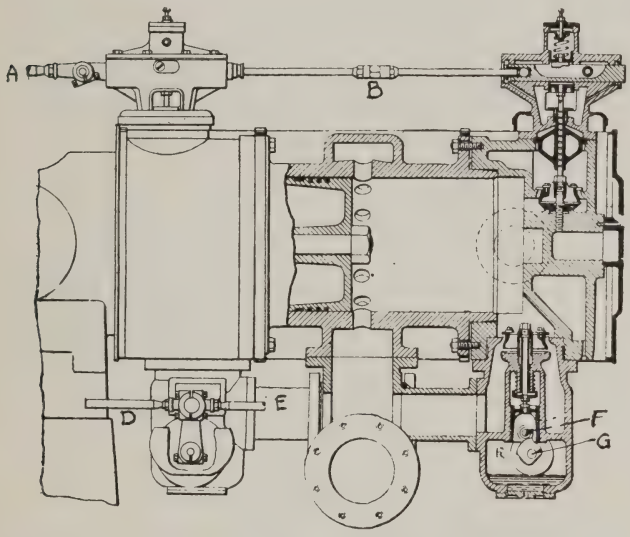



FIG. 32. CONTROLLED COMPRESSION IS OBTAINED BY ADJUSTMENT OF EXHAUST VALVE SETTING

secondary exhaust ports. This construction permits of the compression being controlled at will, as it is possible to vary the time of the final exhaust closure to such an extent that any desired compression pressure may be obtained under widely varying admission.

In setting the exhaust valves remove the covers on the opposite side of the cage from the rocker lever, which will allow a full view of the side of the cams, then turn the engine over in the direction of rotation until it is on its dead center, and make a mark on the side of the crosshead shoe and a similar mark on the crosshead guide directly in line with the one on the crosshead shoe. Turn

the engine to the other dead center and mark it in the same way. This will provide for conveniently measuring the distance the piston may be from the end of the stroke.

Turn the engine over until the piston is within 1 in. of the head end dead center from the expansion stroke and adjust the reach rod D shown in Fig. 32 so that the cam in the crank end cage is just in contact with the roller. Turn the engine over until the valve is seated and measure the distance the piston is from the crank end. This will determine the length of the compression which should be approximately 20 per cent of the stroke in ordinary cases, and in any event will be close enough for preliminary setting. Turn the engine to the crank end dead center and adjust the valve rod E to open the head end valve in the same manner as the crank end valve.

With the valves thus set, the engine may be operated and the rods further adjusted to gain the best results by using the indicator after the engine is in operation. The roller in the small crosshead on the exhaust valve stem should be adjusted through the small rectangular opening on the side of the cage so that there will be about 0.003 in. space between the cam and roller at a point on the round part of the cam just before the lifting part comes into contact with the roller.

### Effect of Valve Adjustments

In Table II the effects of adjustments made on the exhaust rods and change in location of the exhaust eccentric on the shaft are shown. The exhaust valve gear is fully as sensitive to adjustment as the admission valve gear and only slight adjustment will have a pronounced effect on the indicator diagram.

In order to set the valves more accurately, it is necessary to take indicator diagrams after the engine has been operated for a short time and is warmed up. Any adjustments to the valve gear necessary to change the valve setting should be made with a view of properly adjusting the crank end valve first, giving no attention whatever to the head end valve until the crank end valve has been satisfactorily adjusted, bearing in mind that the valve motion is sensitive to adjustment and little change on rods is required to make a material change in the indicator diagram.

With the crank end valve satisfactorily adjusted, the head end valve should be adjusted in the same way. It should be understood that, due to the angularity of the connecting rod and eccentric rod, it is not possible to obtain as good a diagram from the head end as from the

TABLE II. CHANGES IN EVENTS DUE TO VALVE ADJUSTMENTS

Adjustment of Steam Valves.

| Adjustment | Crank End | | Head End. | |
|---|---|---|---|---|
| | Admission | Load | Admission | Load |
| Shortening reach rod A | Later | Lighter | Earlier | Heavier |
| Lengthening reach rod A | Earlier | Heavier | Later | Lighter |
| Shortening ball rods B | Unchanged | Lighter | Earlier | Heavier |
| Lengthening ball rods B | Unchanged | Heavier | Later | Lighter |

Adjustment of Exhaust Valves
(Engines up to and including 30 inch stroke)

| Adjustment | Crank End | | Head End | |
|---|---|---|---|---|
| | Valve | | Valve | |
| | Opens | Closes | Opens | Closes |
| Shortening reach rod D | Earlier | Later | Later | Earlier |
| Lengthening reach rod D | Later | Earlier | Earlier | Later |
| Shortening valve rod E | Unchanged | Unchanged | Later | Earlier |
| Lengthening valve rod E | Unchanged | Unchanged | Earlier | Later |
| Moving exhaust eccentric around the shaft in direction of rotation..... | Later | Later | Earlier | Earlier |
| Moving exhaust eccentric around the shaft in opposite direction of rotation..... | Earlier | Earlier | Later | Later |

Adjustment of Exhaust valves
(Engines 34 - inch to 36 - inch stroke)

| Adjustment | Crank End | | Head End | |
|---|---|---|---|---|
| | Valve | | Valve | |
| | Opens | Closes | Opens | Closes |
| Shortening reach rod D | Later | Earlier | Earlier | Later |
| Lengthening reach rod D | Earlier | Later | Later | Earlier |
| Shortening valve rod E | Unchanged | Unchanged | Earlier | Later |
| Lengthening valve rod E | Unchanged | Unchanged | Later | Earlier |
| Moving exhaust eccentric around the shaft in direction of rotation..... | Earlier | Earlier | Later | Later |
| Moving exhaust eccentric G around the shaft in opposite direction of rotation..... | Later | Later | Earlier | Earlier |

crank end with a shaft-governed engine of any type. In most cases the lead will show later and the admission line will not be as good as for the crank end and, if there is any difference in compression, it will show higher on the head end.

Various indicator diagrams are shown in Fig. 33 which will give a general idea of the type of diagrams from one of these engines.

### Care Should Be Used in Increasing Lead

Care should be exercised when increasing the lead on the valves with the engine carrying a load, that the lead is not increased so much that the governor will lose control of the speed when the engine is operating at friction load. This is quite possible, as the rollers may be adjusted so far under the cams with the engine carrying a load, that when the load is thrown off and the governor is on its minimum

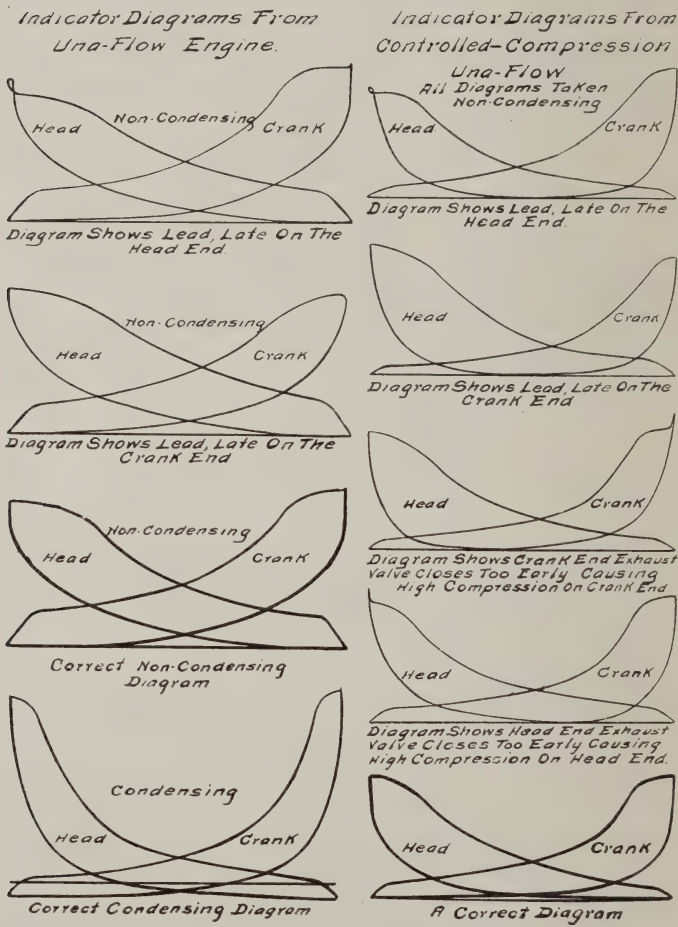



FIG 33. EFFECT OF VALVE SETTING ON INDICATOR DIAGRAMS

travel, the roller may still be coming in contact with the cams and lifting the valve slightly, admitting steam into the cylinder, causing the governor to lose control of the engine.

In this case it is necessary to decrease the lead only to such an extent that the governor will control the engine at the friction load which is a maximum lead and should be given to the valve with maximum steam pressure.

If the engine is to operate sometimes condensing and at other times non-condensing, the valves should be set for

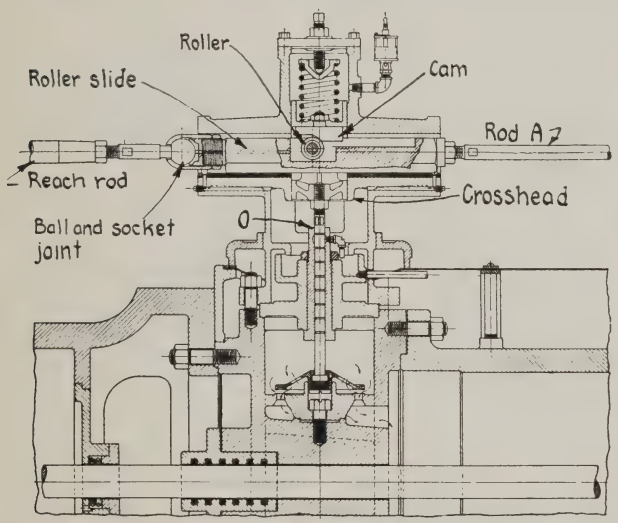



FIG. 34. CAM HEAD AND VALVE OPERATING MECHANISM OF CHUSE ENGINE

the condensing operation as a condensing engine will not operate satisfactorily with as much lead when operating condensing as it will non-condensing, due to the action of the vacuum in addition to the early admission of steam.

### Single-Beat Poppet Valves in Chuse Engine

In the unaflow engine built by the Chuse Engine & Manufacturing Co., admission valves are of the single-beat poppet type. It will be noted from the sectional view of this valve shown in Fig. 34 that the valve assembly con-

sists of a camhead, roller-slide, the valve and valve stem. The roller slide is operated by the rocker arm driven by the governor eccentric. The roller slides under the cam and lifts the small crosshead that carries the valve stem and valve.

In this construction, the valve stem is slipped through the center of the valve and is held in place by a screwed jam-nut. The upper end of the stem screws into a crosshead, which slides in the valve bonnet and carries a cam. A roller is carried on the roller slide which reciprocates in the housing and the roller by lifting the cam opens the valve.

The slide rod is fastened to the reach rod by a ball and socket joint and the reach rod in turn is fastened to the steam rocker arm. This arm is of the indirect type causing the reach rod to move to the right when the eccentric rod and eccentric move to the left.

### Setting Chuse Steam Valves

To set the steam valve it is first necessary to locate the crank in center position and the reach rod is next uncoupled and the rocker arm adjusted so that it travels equal distances from its vertical position. By uncoupling the ball and socket joint it is possible to disconnect the reach rod from the lower slide rod and the top half of the valve may then be removed. This exposes the slide rod and cam of the valve stem crosshead. The slide rod should then be shifted to bring the roller under the high or thin part of the cam. The clearance between the roller and cam should be approximately 0.004 in. This clearance should be carefully checked by slipping a feeler gage between the roller and cam and the valve stem should be screwed in or out of the crosshead to bring this clearance to the value given, if it is not correct. If the clearance is too small when the engine warms up, expansion may cause the valve to remain open at all times.

After adjusting both head and crank end valves the bonnet should be replaced. The next step is to connect up the reach rod and place the engine on crank-end dead center. After this is done, the reach rod should be lengthened or shortened to give the valve a lift of $\frac{1}{32}$ in. with the engine on dead center. To measure this lift a punch mark

should be placed on the upper edge of the valve stem housing, at the part marked O in Fig. 34 and a second one on the valve stem locknut. This should be measured with the valve closed and when the engine is on dead center.

After this is done the engine should be turned to the head end dead center and the rod A adjusted until the head end valve has the same lift or lead.

Where the engine is intended to operate condensing, automatic compression relief valves are provided as a

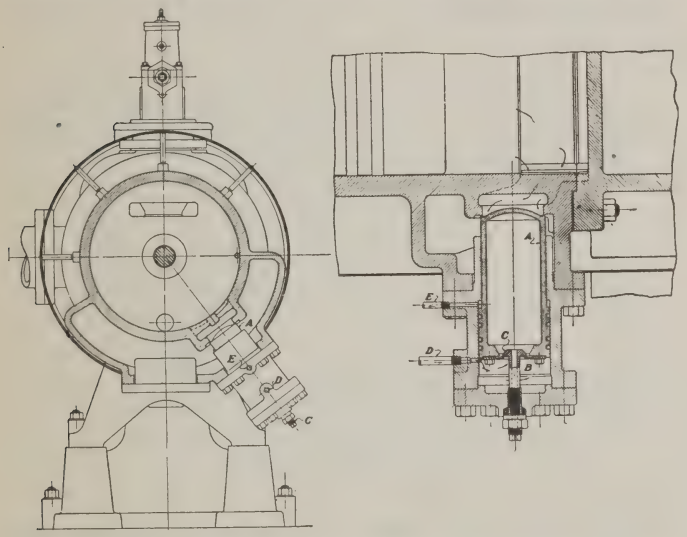



FIG. 35. AUTOMATIC COMPRESSION RELIEF VALVE

safety device to relieve the excessive compression in case the vacuum should become too low or fail all together. One of the automatic relief valves is shown in Fig. 35.

### How Chuse Relief Valves Work

Considering the valve A closed for condensing operation as shown, live steam is admitted through pipe D to chamber B. The excess pressure which holds the valve A closed is due to the greater area of the valve body in chamber B compared to the area of the port leading from the cylinder. This difference in pressure is sufficient to hold the valve A closed under ordinary initial pressure in the cylinder.

If the compression becomes excessive, due to the failure of the vacuum, the valve A is forced off its seat, opening the small valve C and throwing the chamber B into communication with the atmosphere. The large valve is then free to drop to the full opening, allowing free communication between the cylinder and the auxiliary clearance chamber. The valve will remain open as long as the vacuum is below its safe limit.

When the vacuum returns, atmospheric pressure under the valve will lift it as soon as sufficient vacuum is

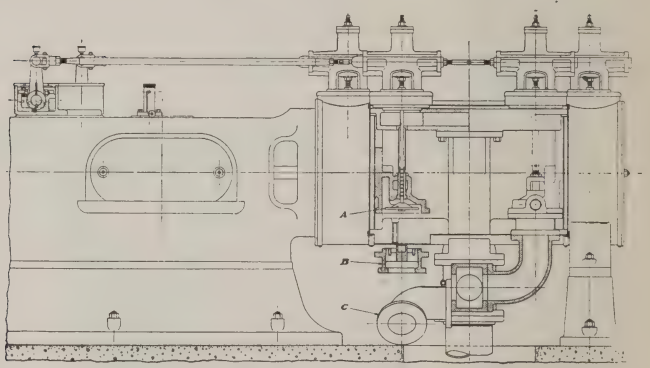



FIG. 36. AUXILIARY EXHAUST VALVES USED FOR NON-CONDENSING OPERATION

obtained. Thus the valve A will close and admit steam through D into chamber B which will again hold the valve in position for condensing operation.

### Non-condensing Operation

Where Chuse engines are designed for non-condensing operation, the same sort of admission valves and operating mechanism is used as on condensing engines. The automatic compression relief valves are replaced by auxiliary exhaust valves, located on the side of the cylinder at the end of the piston travel. These exhaust valves are operated by the same sort of cams and slide mechanism as steam valves, except that they are driven by a fixed eccentric instead of by the governor.

Figure 36 shows the manner in which the auxiliary exhaust valves are located on the cylinder. Part of the

cylinder steam passes out through the center exhaust ports as soon as these are uncovered by the piston. The cylinder is then filled with exhaust steam at atmospheric pressure which is allowed to excape through the auxiliary exhaust valves until about 7/10 of the return stroke is completed.

Steam flows from the ends of the cylinder bore through the passage A and passing around the open valve, enters the central exhaust pipe through the passages B and C.

### Harrisburg Engine Uses Piston Valves

In the unaflow engines built by the Harrisburg Foundry & Machine Works, central exhaust ports are provided but, in place of the customary steam valve for each end of the cylinder, a single piston valve is used similar to the type used on high-speed engines. Another feature of this engine is the use of auxiliary clearance space.

Figure 37 shows the action in diagrammatic form. In position 1, the piston is commencing its stroke, and the valve is just opening and admitting steam. Exhaust is passing to atmosphere through the central ports and emptying the auxiliary clearance chamber EGE. In the second position, the steam valve is open, admitting steam behind the piston and the exhaust valve is open at the opposite end. The central exhaust ports are closed and compression is beginning in the cylinder and auxiliary chamber EGE. In position 3, the piston is in the position of cut-off, the valve having reversed its movement, and the admission ports are closed shutting off the supply of steam to the head end of the cylinder. Expansion commences with the exhaust ports still open at the opposite end and compression continues in the auxiliary clearance chamber EGE.

As shown in position 4, the outer edge of the valve opens the port at the head end, allowing steam from the auxiliary clearance chamber EGE to pass into the cylinder, mixing with the expanding steam and expanding with it until the central exhaust ports are open to the atmosphere. In the mean time the opposite end of the valve has closed the exhaust ports and compression occurs in the cylinder and cylinder clearance only.

At position 5, the central exhaust ports are uncovered by the piston and the steam is exhausted reducing the pres-

sure in the cylinder and auxiliary clearance chamber EGE to exhaust pressure. At position 6, the stroke is completed and the piston is at the end of the cylinder ready for the return stroke. In this position the valve is opening to admit steam to the crank end the exhaust valve at the opposite end is still open and head end exhaust continues.

For condensing engines, clearance pockets are provided, which are placed in communication with the cylinder by hand-operated valves, should the engine be required to run non-condensing.

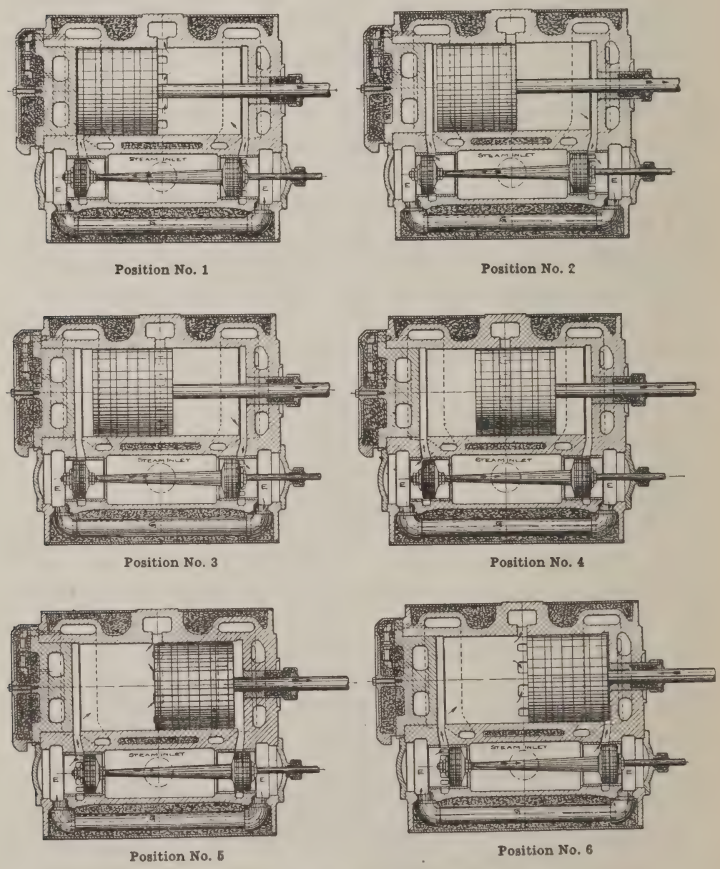



FIG 37. CYCLE OF OPERATION FOR THE HARRISBURG ENGINE

In Fig. 38 are shown the types of valves which are used in this engine. They are the balanced piston type made with adjustable steam-packed rings and operate in removable cages or bushings. For the smaller sized engines the single ported type is used, while the larger engines are fitted with the double ported valve.

### Setting Harrisburg Piston Valves

While the general method used in setting piston valves is applicable to setting the valves of the Harrisburg unaflow, the procedure will be taken up detail. After the crank dead center has been located the eccentric rod is

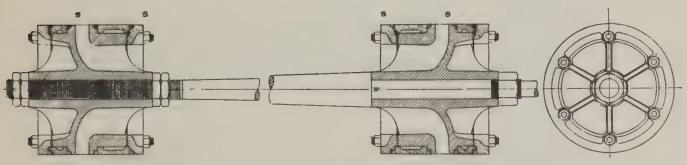


FIG. 38. TYPE OF PISTON VALVE USED IN HARRISBURG ENGINE

adjusted in length until the valve block to which this eccentric rod is pinned, moves equal distances from the center of the valve block guide when the eccentric is moved to the two extremes of its throw. After this has been done, the valve is disconnected from the block and drawn out of the steam chest. Templets of the valve and the valve bushing ports are made as outlined in the method for setting piston valves.

Templets of the valve and the valve bushing ports are made and the distance of each port edge from the face of the steam chest is measured by the measuring rod. The port dimensions, as well as those of the valve, are marked off from the point X, as shown in the Fig. 39.

The valve templet is then shifted until it covers the head end and crank end steam ports by equal amounts, so that there will be equal laps. The distance from X to the valve templet is measured and replacing the valve in the steam chest end with the eccentric in mid-position, or the valve slide block at the center of its travel, the valve rod is adjusted until the end of the valve is the same distance

from the face of the steam chest as is the valve templet when set with equal laps. The governor weight should be placed in the normal position for full load conditions. The engine should be set on head and crank dead centers, and the position of the valve measured and transferred to the templet. If the valve has been set properly, the leads should be equal.

After this is done the governor spring should be removed and the weight arms shifted to their extreme outward or no load position. The travel of the valve should

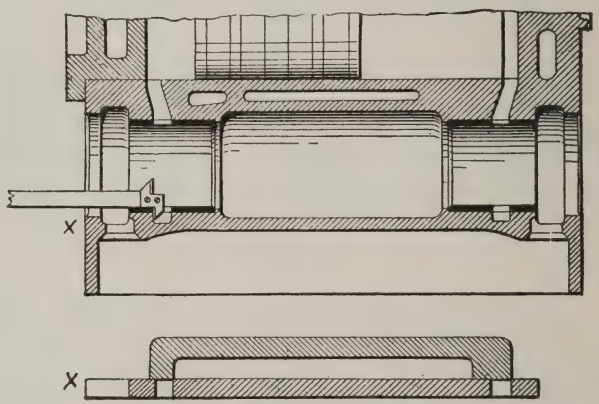



FIG. 39. MEASURING VALVE PORTS FOR TEMPLET

be checked and referred to the templet to determine whether the valve uncovers the ports. If the port is uncovered, it will be necessary to remove the valve, and screw the ends together until the amount of lap is sufficient to keep the valve closed when the governor is at its outermost position.

It is important that the compression be kept below the initial pressure by 5 to 10 lb., which can be checked by means of indicator diagrams. If it is desired to increase or decrease lead, this can be done by nuts on the valve stem where the valve heads are locked. To increase lead lengthen the distance between valve heads and, to decrease lead, shorten this distance.

## CHAPTER VII

## HAMILTON, KINGSFORD, MURRAY AND NORDBERG VALVES

ONE point of difference in the Hamilton unaflow engine which is built by the Hooven-Owens-Rentschler Co. makes it rather distinctive. The steam valves are placed horizontal at the bottom of the cylinder as illustrated in Fig. 40. These valves are of the double-beat poppet type and seat in removable cages. They are driven by an eccentric operated by a lay shaft running along the frame, which shaft is connected to the crank shaft by double gears and a drag crank. The exhaust valves, which are on top the cylinder, are also driven by this lay shaft.

In the steam valve the cam end of the valve stem fits into a crosshead X carrying a roller, Y. This roller makes contact with the cam, Z, which is clamped on the short steam cam shaft, W. This cam shaft is driven by the steam eccentric rod, O, by means of a rocker arm clamped to the steam cam shaft. Only one steam eccentric is used, the two valve cams being fastened to the one steam cam shaft.

### Setting Hamilton Valves

When setting valves, the first step is to make sure that the rollers and cams are in proper contact. If properly adjusted, the back of the cam is exactly vertical, when contact is made with the roller.

Adjustment of the eccentric rod is then made, so that the distance from the center of the eccentric strap to the center of the stub end is $\frac{1}{8}$ in. less than the distance from the center of the cam shaft to the center of the governor or eccentric shaft. This stub end is now connected to the cam shaft lever and the side shaft coupling is disconnected, so that the part of the lay shaft carrying the governor and eccentric is free from the portion geared to the engine shaft.

After this is done, the governor is turned to bring the slide block at right angles to the eccentric rod, which is

determined by the fact that, when the position is reached, it is possible to move the governor in and out without moving the cam shaft lever. This is the lead position.

With this engine is furnished a dial which may be clamped to the governor shaft and set to indicate the per-cent lead. If this dial is used, it should be set at 2 per

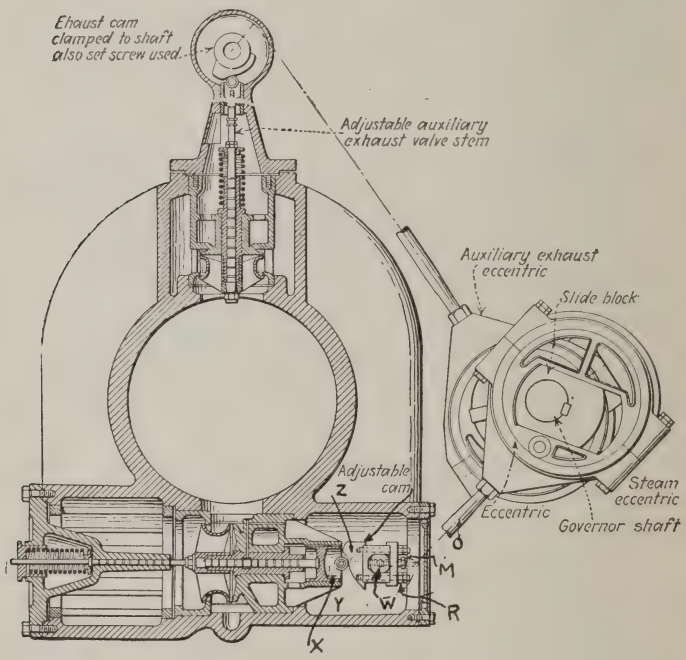



FIG. 40. HORIZONTAL VALVE USED WITH HAMILTON ENGINE

cent lead. If the dial is not available, marks can be made on the shaft and bearing.

Revolve the shaft one-half turn and the other cam should just begin to push its roller at 2 per cent lead. This should be the condition when the governor springs are removed and the weight blocked half way out. When the governor weights are at the extreme outer position, the valve should not be opened at all by the cam. When the weights are entirely in, the maximum opening and cut-off are obtained.

In this engine, the cut-off and openings are equalized by changing the length of the eccentric rods and the lead is changed by shifting the governor shaft coupling so that the eccentric is advanced with reference to the crank pin.

When the engine is tested at the factory, a mark is made on the coupling opposite the pointer mark on the bearing and stamped "crank-end center." The shaft is then turned a slight amount until the dial shows crank-end lead and another mark is placed on the coupling and lettered "crank-end lead." These two marks make it possible to check up the valve setting at any time.

Where the engine is to be used for condensing operation, it is fitted with auxiliary exhaust valves placed at the top of the cylinder. These valves are of the double beat type and are controlled by cams fitted to a short cam shaft along the cylinder top, which is driven by a single exhaust eccentric from the main layshaft.

### Relief Valves for Condensing Service

Where the engines are used for condensing service, relief valves are placed at each side of the cylinder and communicate with a clearance belt or passage around the cylinder. If it is desired to run non-condensing, these valves are opened by hand and add the auxiliary clearance volume to the normal cylinder clearance.

When setting the exhaust valve, the exhaust eccentric rod should be disconnected from the camshaft rocker, and the exhaust cam should be adjusted for quiet operation by screwing down the cap nut on the end of the exhaust valve stem, until the valve is too short. The nut is then gradually screwed up until the noise disappears, although a precaution should be taken that the stem is not left too long. The eccentric rod is then reconnected and the cams are set by shifting the exhaust eccentric to its position of minimum travel.

Next the governor shaft is rotated until the exhaust cam shaft is at one extreme of its travel, and the proper cam is set to bring its flat side level or horizontal. After this it is necessary to rotate the governor shaft about one-half a revolution or until the other extreme of the cam shaft oscillation is reached. Then the second cam is clamped with its flat side level. The check on whether the

proper setting has been made, is to turn the governor shaft through an entire revolution. If the exhaust valve does not open, the setting has been properly carried out.

When the eccentric is shifted to any position other than that of least travel, both valves should have equal lifts. This exhaust valve gear is so designed that the valves open at about 6 per cent of the stroke past dead center and may be adjusted by the hand wheel to close at any point in the exhaust stroke up to 95 per cent. The lead is always constant.

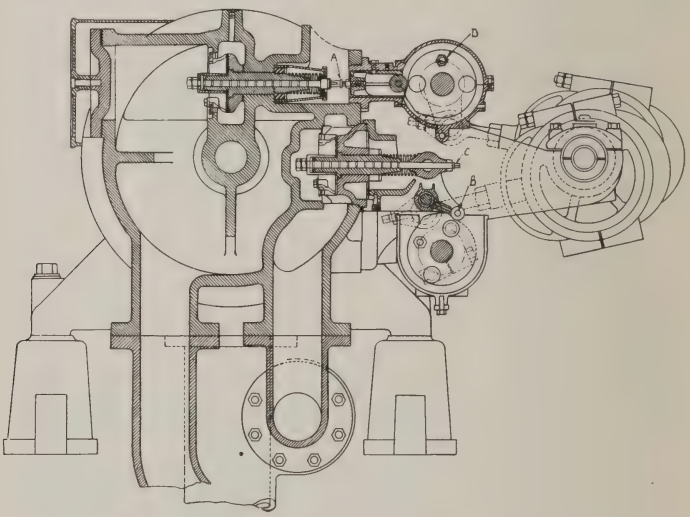



FIG. 41. VALVE GEAR OF KINGSFORD ENGINE

Set the engine crankpin on the crank-end dead center, rotate the governor shaft until the index of the bearing shaft coincides with the line marked "crank-end center" on the coupling and clamp the coupling. This completes the valve setting.

### Kingsford Unaflow Engine

Figure 41 shows a cross-section through the valve gear of the unaflow engine built by the Kingsford Foundry & Machine Works. This view shows the crank on the head-end center with the active part of the head-end steam cam and crank end exhaust cam about to engage in the opening of their respective valves. Similar conditions, apply

with the crank on the opposite or crank-end center. The location of the keyways in the cam shaft (steam and exhaust) and lay shaft for the eccentric and governor are determined from the valve diagram.

To set the cams so as to give correct timing of valve opening is a simple matter, and the general procedure is as follows:

Place the engine in any position off center so that the inactive part of the cam face engages the roller (steam or exhaust). Give the steam valve tappet about 0.006 in. clearance and the same clearance for the exhaust, measured by slipping a feeler gage under roller B and making adjustment at C.

The next step is to turn the engine over and place the crank on either center. To simplify matters, we will place the crank on the head-end center and follow the points of adjustment from the drawing which, as previously mentioned, shows the position of cams with crank on head end.

For good running conditions 0.003 in. clearance between cam face and roller is sufficient. Try a 0.003 feeler between steam tappets at A and, if this space is greater, slack nut on eccentric pin D, and with a small wrench on the square head turn the cam clock-wise until the 0.003 feeler pinches at A. This completes the setting of the steam cam. Give the exhaust cam the same clearance and proceed in a like manner with crank on opposite end.

The final valve adjustments should of course be made with an indicator.

For control of the steam valves, a centrifugal inertia governor is used, mounted on the lay shaft and equipped with two eccentrics, primary and secondary, which combination is dead beat.

The primary eccentric is keyed to the lay shaft and the secondary is connected to the governor weights by means of links. This combination of double eccentrics is also used for the exhaust valve drive with the secondary adjustable to vary the compression.

### Murray Unaflow Engines

As will be noted from Fig. 42, the unaflow engine built by the Murray Iron Works Co. utilizes the poppet type of valve. These valves are of the double-beat type with the

lower valve seat attached on the valve body, while the upper valve seat is a light flexible steel disk held to the valve body by set screws. It is stated that the use of one flexible seat reduces the possibility of steam leakage, which exists when the entire valve is made in one piece. The upper valve disk rests on a seat turned on the head casting, while the lower valve edge rests on a seat that is a separate casting held to the cylinder head by a cap screw.

Referring to Fig. 42 the valve rod marked X is driven by the governor eccentric and to this rod are fastened two

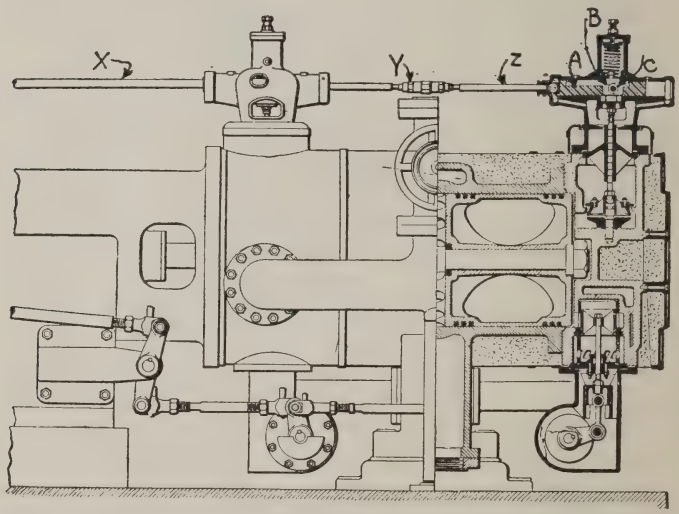



FIG. 42. VALVE ARRANGEMENT OF MURRAY UNAFLOW

steel blocks A, one to slide in each valve bonnet. Each block carries a roller which makes contact with a cam block B, placed on a crosshead fastened to the valve stem. The roller C, due to the reciprocating motion of the valve rod, makes contact with the cam B raising the valve stem and so admitting steam to the cylinder.

When the valves are set, the engine is turned over until the roller C is under the flat surface of the cam D. The valve stem is then turned until the clearance between the cam and roller is 0.002 in. which insures that the valve will be closed when its roller is under the flat surface of the cam.

## Adjusting Murray Valves for Lead

Lead is adjusted by uncoupling the valve rod X and setting the eccentric rod so that the rocker arm travels equal distances each side of its vertical position. This reach rod, X, should then be adjusted to a length such that, when the engine is on crank dead center, the roller just touches the cam of the crank-end valve.

Next the rod Z is adjusted by the turn buckle, Y, so as to cause the head-end valve roller to touch its cam, when the crank is at head-end dead center.

This engine also uses auxiliary exhaust valves, which are of the solid piston type and are moved by a fixed eccentric, through a linkage as shown. In order to set the auxiliary exhaust valves an opening is provided into which a relief valve is screwed so that the engineer can see the auxiliary port slot through the exhaust valve cage. The valve is set so that the top edge is in line with the lower edge of the slot when wide open; that is, the valve opens wide without any over travel. When closed, the lap is practically one and one-half times the length of the slots. This is necessary in order to keep the valve closed during half the engine's revolution. After setting the two auxiliary valves so that their travels and positions are as near alike as possible, by changing the valve stem and reach rod length, the exhaust eccentric should be shifted to give a small amount of lead with the engine on dead center. If the valves do not show the same lead, correction may be made by adjusting the rocker arm to get equal travel each way from its vertical position and by changing the length of the reach rod.

As in other types of engines, it is recommended that final adjustment of all valves be made, after the engine has been run awhile, by taking indicator diagrams. Auxiliary exhaust valves must be set to give correct compression for the existing back pressure and, when operating condensing, the auxiliary valves are uncoupled or left off entirely.

In this engine the cylinder body is not steam jacketed but is covered with several inches of insulating material. Steam is admitted to each cylinder head through a cast-iron pipe connection and the cylinder heads are steam

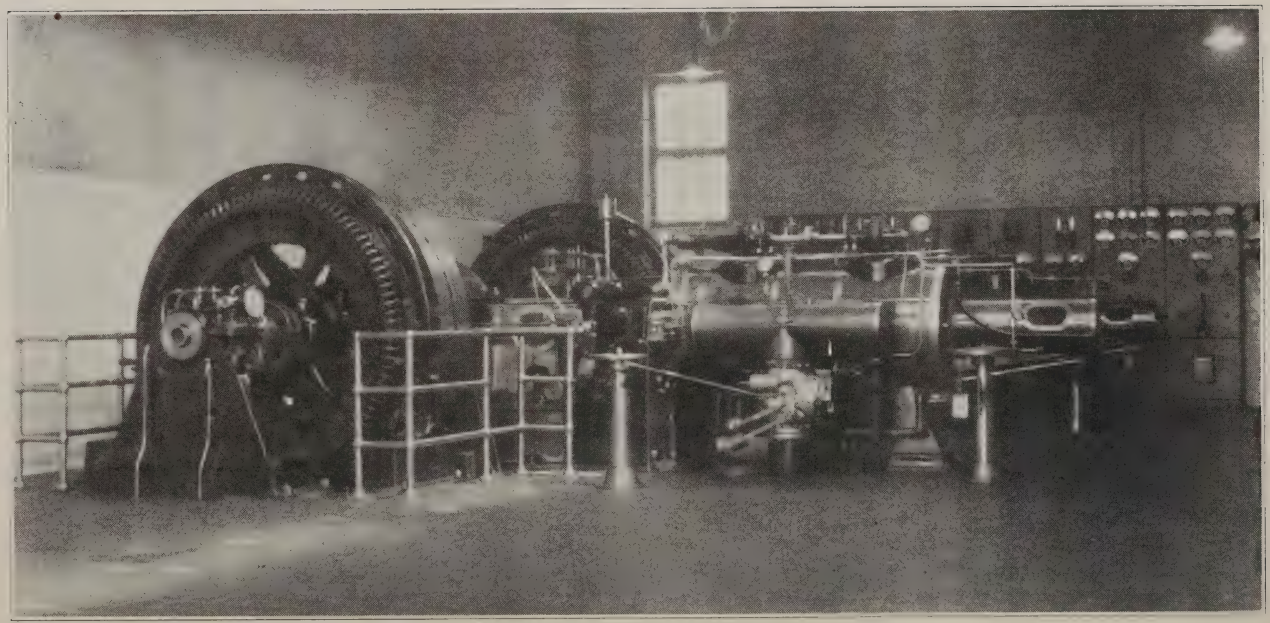


FIG. 43. TYPICAL INSTALLATION OF A UNAFLOW ENGINE

jacketed, the faces forming the steam chest for the engine. In this way condensation is reduced to a minimum.

### Nordberg Valves Driven by Layshaft

In Fig. 44 is shown the valve arrangement of the unaflow engines built by the Nordberg Manufacturing Co. As shown in this sectional view, both the steam and exhaust valves are driven by means of a layshaft upon which the

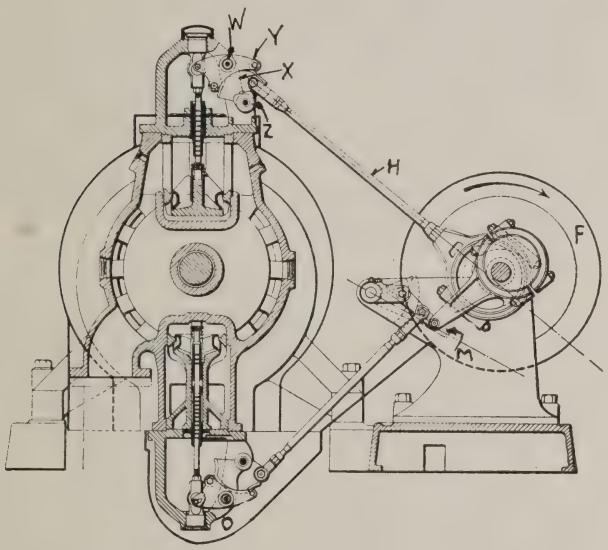



FIG. 44. NORDBERG VALVES ARE PLACED IN CAGES

eccentrics are placed and which is driven by the crank shaft through bevel gears. A centrifugal type of governor, connected to the steam eccentric by a sleeve, controls the engine speed by altering the eccentric travel and the lift of the steam valve.

Valve action is obtained by the use of cams. Both the steam and exhaust valves are arranged in cages which set into the cylinder casting.

Referring to Fig. 44 both steam and exhaust valves are operated by a cam lever which is actuated by a cam and rollers. When eccentric rod H moves upward, the cam X is rotated inwardly. This cam makes contact with the

opening roller and at the same time the back part of the cam X which is depressed comes under the closing roller Y. The steam reach rod H, as it moves upward, causes the cam to push the roller D upward and the cam lever A moves about the fulcrum pin W. This causes the valve to lift off of its seat and admit steam to the cylinder. As the eccentric continues on around its circle, the operation is reversed, and since the cam has a steep slope at the points of contact with the roller, opening and closing of the valves are rapid.

When the valve seats, further travel of the cam causes the valve stem to compress the valve spring, insuring positive valve closing and also exerting downward pressure on the valve when it is seated. These cams carry two marks, one showing the exact point of closure of the valve and the other showing the point where the connecting spring first comes under full compression.

### Cam and Roller Clearance

When setting the valve, the fulcrum D of the cam is turned eccentric so that the cam can be adjusted with the proper amount of clearance between the cam and roller. As in other valve settings which have been described, this clearance is about 0.003 in. In adjusting the length of the valve stem, care must be taken that the compression of the spring does not become excessive. In making this adjustment, the engine should be turned to a point where the valve is closed and the stem then adjusted so that the coils of the spring are not forced together so much that contact is made between the coils.

The actual valve setting is carried out along lines which have been described. First the engine is turned to dead center, the governor weights are blocked in the outermost position and the eccentric rod is adjusted so that the valve is not lifted but remains seated. In this case the cam should clear the cam lever roller.

### Provision for Non-condensing Operation

In order to take care of either condensing or non-condensing operation, the exhaust cam is made with exceptionally long contact faces so that, when operating condensing, the valve can be kept closed and the rollers kept

in contact with the cam while the eccentric is giving the full stroke to the cam. The opening point of the exhaust valve is not so important but the point of closing must be set according to the operating conditions desired. This point of closing of the exhaust valve is changed by changing the effective length of the exhaust eccentric rod. This is done by introducing a combination lever M, which is carried by a rocker, the rocker arms for both the exhaust valves being adjusted by means of one hand lever. This adjustment can be made when the engine is in operation. By placing the hand lever in different positions, the point of closing of the exhaust valve can be changed as desired to fit any operating conditions.

## CHAPTER VIII

## RIDGEWAY, SKINNER AND WORTHINGTON VALVE SETTING

ADMISSION valves of the unaflow engines built by the Ridgway Dynamo & Engine Co. are of the double-beat poppet type and are placed in the cylinder heads. In order to compensate for slight variation in vertical distance between the upper and lower seats, such as might be caused by expansion due to temperature changes, the upper lip of the valve is made thin enough to have slight flexibility. The steam pressure above then aids in forcing the valve tightly on both seats and steam leakage is prevented

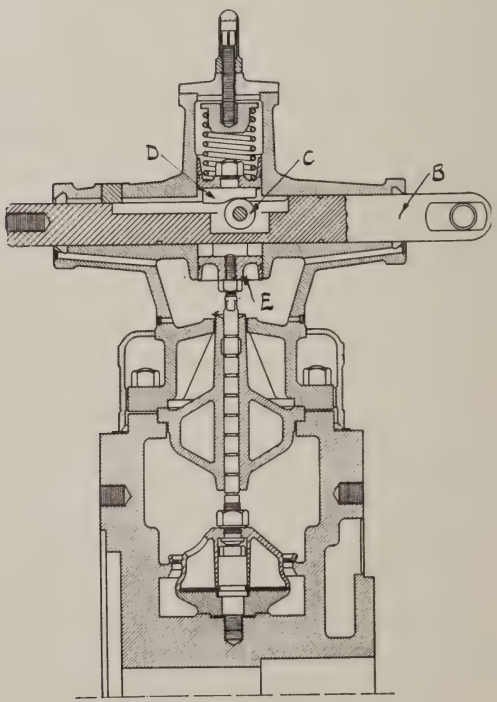



FIG. 45. ADMISSION VALVE OF THE BIDGEWAY ENGINE

Motion from the governor eccentric is transmitted through an operating rod on the top of the bed, to the ram passing through the upper part of the valve bonnet. This ram carries a hardened and ground steel roller which, coming into contact with the cam above it, raises the steel sleeve to which the valve rod is connected, and in turn lifts the valve. Figure 45 shows the construction of the valve and lifting mechanism and the means provided for adjusting various parts. The valve stem passes through a

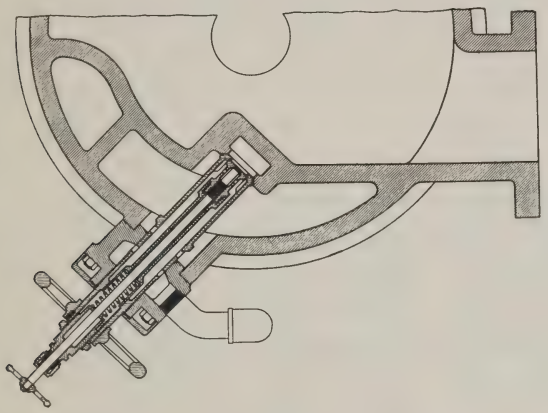


FIG. 46. RELIEF VALVE USED IN CONDENSING SERVICE

long guide or stuffing box. A series of grooves is turned on the stem and these grooves, becoming filled with water, form an effectual seal against steam leakage.

### Arrangement for Condensing Service

Engines built for condensing service have an auxiliary clearance space in each head. The connection to this space is through a combination drain, relief and clearance valve, a section of which is shown in Fig. 46. The large hand wheel opens the connection to the clearance space and the small wheel opens the drain.

Between these valves is a spring-loaded relief valve which can be adjusted by an outside nut. When the engine is operating condensing, the clearance valve is closed. Should the vacuum fail, the relief valve will open to prevent excessive pressure, until such time as the clearance

valve can be opened by hand, under which condition ample clearance space is provided for non-condensing operation and, at the same time, the relief and drain portions of the valve function as before. Engines designed for non-condensing service only, have pistons with concave heads to provide the volumetric clearance necessary to prevent excessive compression.

### Arrangement of Ridgeway Valves

In Fig. 47 is shown a sectional view of the cylinder which gives an idea of the arrangement of the valves.

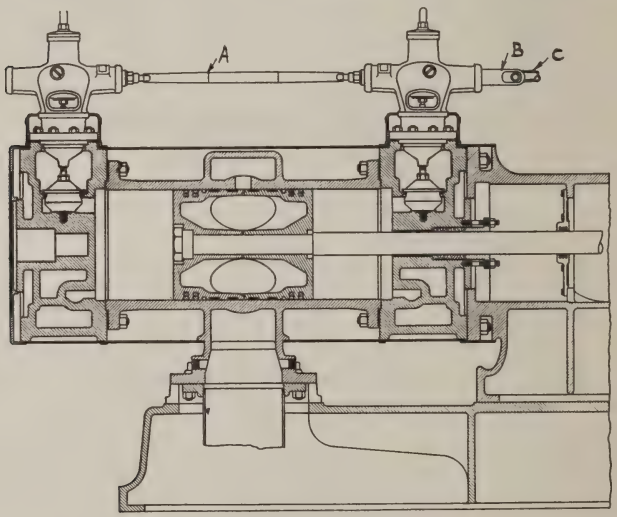



FIG. 47. VALVE ARRANGEMENT IN THE RIDGEWAY ENGINE

Referring to this figure and the previous illustration showing the section of the steam admission valve, the operation of the valves is as follows: The reach rod C is operated by the governor-controlled eccentric, the motion being transmitted through an eccentric rod and rocker arm, through the cam rod B. The roller C which is a part of the cam rod B comes in contact with the cam D and operates the valve.

Setting the steam valve is a procedure quite similar to that followed in similar types of valves previously described but will be reviewed briefly. The reach rod D is first dis-

connected, and the length of the valve stem is adjusted to give a clearance between the cam D and the roller C of 0.002 in. when the roller is under the thin part of the cam. This clearance must be kept small as, if it is made much greater, there will be a pound when the roller strikes the cam while the engine is running.

### Reach Rod Adjustment

After reconnecting the reach rod to the cam rod B, the engine is turned over until it is within 1 per cent of its stroke of reaching crank dead center. This is the lead point and the reach rod C should be so adjusted that the valve will start to lift at this point. In a similar way the

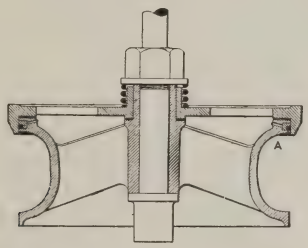



FIG. 48. EXPANSION RINGS PREVENT LEAKAGE IN SKINNER VALVES

engine is turned over in its running direction until within 1 per cent of the stroke, of head dead center. In that position the head-end steam valve is set to cause the valve to start to open. This adjustment is made by altering the length of the tie rod connecting the two cam rods. This tie rod has right and left hand threaded ends so that it is easily possible to change the distance between the cam rods.

As in other engines, it is recommended that the engine be run for a time and indicator diagrams taken. If the lead is not correct, the proper change in timing should be made. It is also advisable to check the cam clearance when the engine is hot, as the engine will take steam for the full stroke unless there is some clearance between this cam and its roller.

## Skinner Unaflow Engines

Unaflow engines built by the Skinner Engine Co. utilize a steam valve of the double-beat poppet design. This valve also is of a design which eliminates leakage due to unequal expansion of the valve and cylinder head. Figure 48 shows how the top portion of the valve is separated from the valve body and is held down by spring tension. Expansion rings shown at A prevent steam leakage between the two parts of the valve as any inequality of

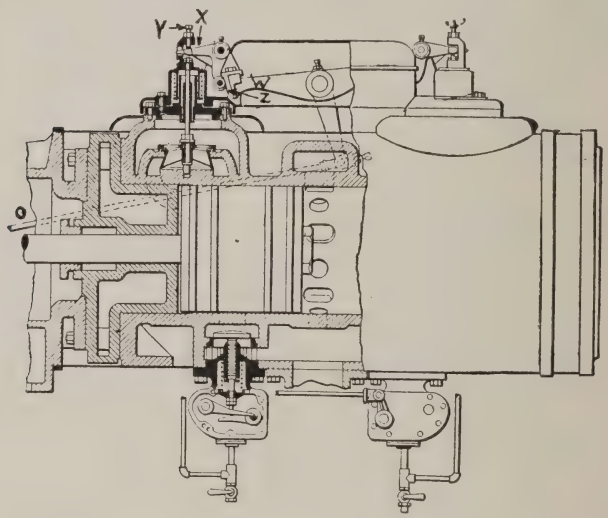



FIG. 49. VALVE MECHANISM OF THE SKINNER ENGINE

expansion of the valve is compensated by a slight displacement of the upper part of the valve body.

Figure 49 shows how these valves are set in the cylinder and also the actuating mechanism which is used. In this arrangement the steam valves are operated by a bell crank marked X. This crank carries a roller which makes contact with the cam Z which is a part of the rocker W. Movement of the rocker is obtained by the movement of the reach rod, O, from an eccentric which is controlled by the governor.

## Procedure in Setting Valves

Valves of this type are set by blocking the governor weight in its outermost position as this is the over-speed

position of the governor. When the governor is in this position, the engine is turned in the running direction and the reach rod and cam rocker W are adjusted until the cam just fails to open the valve. This prevents the engine from taking steam when the governor is in the over-speed position.

Next, the steam valve is lifted by the end of the rocker X touching the set screw Y. When the engine is turned beyond the cut-off position, there must be a clearance between the end of the rocker and set screw, so that the

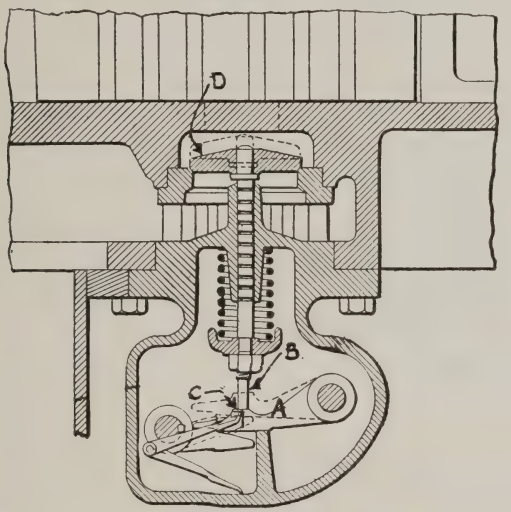



FIG. 50. AUXILIARY EXHAUST VALVES OF SKINNER ENGINE

valve will be held open. Clearance at this point should be about 0.003 in. When the set screw has been adjusted to this clearance the engine is turned to crank center. Then the governor is blocked in its usual running position and the valve reach rod is adjusted so that the rocker X just makes contact with the set screw Y when the crank is on dead center.

After this is done, the engine is turned to the head-end dead center and the reach rod is adjusted so that the rocker X just strikes the set screw Y on the head-end valve. The valves are now correctly set, although as a precaution it is well to block the governor again in the extreme outer

position and check the clearance between the cam and the rocker.

### Auxiliary Valves

In Fig. 50 is a sectional view of the auxiliary exhaust valves which are used with the Skinner engine. In setting these valves, it is necessary that the eccentric rod be of such length that the rocker arm to which it is attached will move the same distance from its vertical position, when the eccentric is moved to its two extreme positions. The next step is to determine the lift of the valves. This is done by removing the covers from the sides of the exhaust cam boxes after draining out the oil. Chalk is then rubbed on the sides of the cam shifter A, which is under the exhaust valve stems B, and a vertical line scribed on it, in line with the valve stem. With the calipers resting on the inside of the bottom of the exhaust-cam box, scribe a line on the side of the cam shifter when the exhaust valve D is down on its seat in a closed position. After this is done, turn the engine and scribe a line on the side of the shifter when the valve is in its topmost position. The difference between these lines represents the lift of the valve which should be as follows:

| Engine Stroke | Lift of Valve |
|---|---|
| 15 in. | $\frac{5}{8}$ in. |
| 16 in. | $\frac{5}{8}$ in. |
| 18 in. | $\frac{3}{4}$ in. |
| 20 in. | $\frac{3}{4}$ in. |
| 22 in. | $\frac{13}{16}$ in. |
| 24 in. | $\frac{13}{16}$ in. |
| 26 in. | $\frac{13}{16}$ in. |
| 30 in. | 1 in. |
| 36 in. | 1 in. |

It is possible to regulate the valve lift by movement of the exhaust reach rod, which has right and left hand threads. In making the adjustment the crank-end valve should be adjusted before the head-end valve. When the exhaust valves are closed, the end of the stem should clear the shifter by the thickness of an indicator card. In checking the wide open position of the valve, it is well to make sure that it is not striking anywhere, at its extreme normal lift, by opening it a little farther with a lever.

### Shifting the Eccentric

When the rods have been adjusted for proper lift, the time of opening and closing may be regulated by adjusting the eccentric on the engine shaft. It should be shifted so that the crank-end valve will close just before the piston reaches the crank end of its stroke. When it has been set in this position, the crank-end valve will open immediately before the piston reaches the head end of its stroke.

In a similar way the head-end exhaust valve should be checked to close just before the crank is on the near dead center and to open before the crank is on the far center. It will be found that the eccentric is marked on the side toward the engine bed corresponding to a mark on the shaft which shows the setting made at the time the engine was under test at the manufacturer's shop.

In large engines of the Skinner type, a slight change is made in the type of valve gear which is used. Although the valve itself is identical with those shown, the cam rockers are mounted on a shaft running along the cylinder which is driven by a linkage from the governor eccentric. The face of the valve cam is also made wider so that the valve-lifting lever and roller slide along the face when the cylinder expands on warming up. The method of setting the steam valve is the same, however, as for the smaller engines.

### Worthington Unaflow Compressor

Valves in the unaflow engine-compressor which is built by the Worthington Pump & Machinery Corp. are set horizontally in the bottom of the cylinder head as shown in Fig. 51. These valves are of the double-beat poppet type. The cast-iron valve body M slides on an extension O of the valve bonnet. The valve rests on the cylinder head casting and carries seat R which is a light steel ring shrunk onto the valve body. This ring is somewhat flexible and it takes care of the difference in expansion of the cylinder head casting and valve body.

It will be noted that the valve stem has a spiral groove in in it. Oil passes along the groove to the end of the valve and so lubricates the valve stem and sleeve.

Operation of this valve is due to the rotation of a lay shaft geared to the crank shaft. Two cams, one for each

cylinder end are fitted to a cam shaft, which is engaged by the lay shaft by means of a feather key. One of these cams is shown in Fig. 52. The rotation of the lay shaft causes the nose of the cam to strike the cam lever roller, which is connected by a link X to the valve lever Y. The motion of the cam is thus transmitted to the valve which is lifted off the seat and steam is admitted to the cylinder. At Z is the valve tappet which is engaged by the cam lever Y.

It will be noted that the governor fits directly over the governor box and is driven by means of double gears from

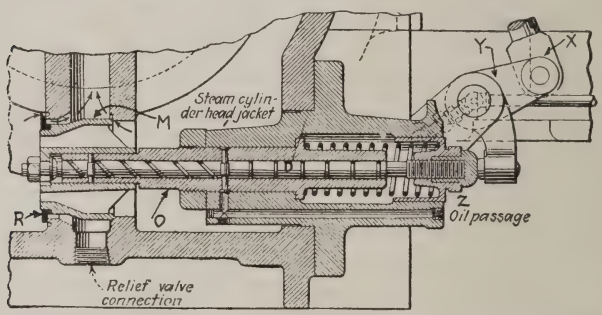



FIG. 51. HORIZONTAL VALVES ARE USED WITH WORTHINGTON ENGINE

the lay shaft. As the engine drives a compressor, there is also a pressure governor mounted on the base plate between the cylinder housings. This governor is of the diaphragm type and the discharge air pressure operates a small pilot valve which in turn admits liquid pressure to the operating piston. Movement of the piston is transmitted through an adjustable rod to a push pin which, pressing against the bell crank, moves the cam shaft. When the compressor is operating below the discharge pressure for which the governor of the engine is set, the engine will run at maximum speed for which the speed governor is set. As soon as the air pressure reaches the desired maximum, a bell crank shortens the cut-off and slows down the machine.

In engines of the duplex type, that is with two parallel cylinders, two sets of cam rockers are provided for each

cam, as shown in Fig. 52. This shows how the valve rod connection is made to the opposite cylinder. The main engine cranks are set at 90 deg. and the rollers in contact with the head-end cam are spaced at 90 deg. as are also the rollers of the crank-end cam. The cams are keyed to the shaft at 180 deg.

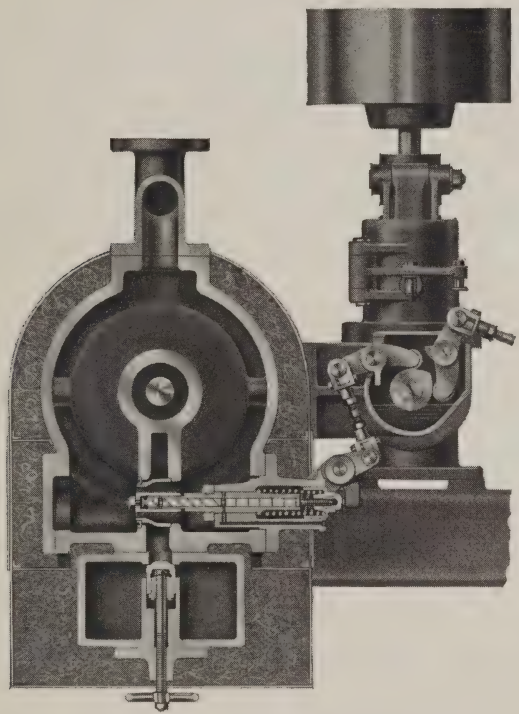


FIG. 52. VALVE OPERATING MECHANISM

Since the setting of the four steam valves is fixed in this way, the only valve setting necessary is the exact position of the bevel gear on the main engine shaft, as the position of this gear determines the lead or admission. The lead should be such that the steam valve is $\frac{1}{32}$ in. open when the engine is on each dead center.

It is advisable to determine the exact position of this gear by the use of an indicator. The lobe of the cam is tapered so that, with the speed governor in its lowest pos-

sible position, the cut-off in each cylinder is approximately 50 per cent, while with the governor in its highest possible position, the cut-off is zero. As the admission side of the cam lobe is a straight line parallel to the axis of the camshaft, the same admission point is maintained regardless of cut-off. The back or cut-off part of the cam is tapered so as to give the range of cut-off as stated.

Clearance of the valve tappets should be about 0.002 to 0.003 in. when the engine is warmed up. This adjustment is made by changing the length of the valve rod X and the amount of clearance can be determined by inserting a thickness gage between the tappets. This clearance should be checked when the roller is on the base circle of the cam and not on any part of the lobe. If the clearance is not correct the valve will be noisy, will have insufficient lift or will remain slightly open at times resulting in a loss of economy.

Although no auxiliary exhaust valves are used with this engine, it is built for non-condensing operation by the use of clearance chambers which are attached to each of the heads. These clearance chambers are opened by means of hand-operated valves which throw them into communication with the cylinder. When the engine is built primarily for non-condensing service, the required clearance volume is secured by making the face of the piston concave.

## CHAPTER IX

## GOVERNING THE ENGINE

POWER developed by an engine may be altered by changing either the initial pressure or the point at which the engine cuts off. In the former case the area at the top of the indicator diagram, as shown in Fig. 53, is reduced, while in the latter method the expansion area is reduced.

### Throttling or Variable Cut-off Used

Governors operate on one of these two principles, although the throttling type is uneconomical since the steam is developed at high pressure and used at a lower

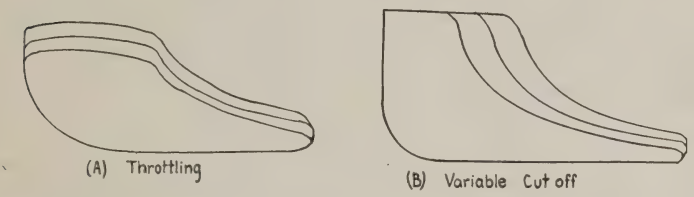



FIG. 53. CHANGES IN CARDS CAUSED BY TWO METHODS OF GOVERNING

pressure, thus cutting down the possible efficiency of the cycle. For this reason the use of governors for larger engines has been mostly confined to the variable cut-off type.

For varying the cut-off two methods are used; that of detaching the valve from the eccentric and closing it by a spring or dash pot and that of shifting the eccentric so as to alter the lead or travel or both. In the first method, the governor controls the point at which the valve is released from the eccentric and in the second method the eccentric is either turned around the shaft or is swung across the shaft on a pivot pin.

As the detaching governor acts only on the cut-off, it alters no other event in the valve operation. While this has certain advantages, the type of mechanism used limits

it to low and medium-speed engines. If the eccentric operating the main valve is turned about the shaft, all of the events of the stroke are changed. It is desirable that the exhaust and compression be altered but little, hence this type of governing has to be designed with that point in view. It is well adapted to control riding cut-off valves through a separate eccentric, the main eccentric being fixed.

It is possible to pivot the swinging eccentric so that it will increase the travel of the valve and thereby lengthen the cut-off and, at the same time, it may increase or decrease the lead at the will of the designer. As a matter of fact it is desirable to have the lead decreased as the cut-off is shortened, in order to avoid over speeding the engine at no load. Increasing the travel gives earlier admission, later cut-off, earlier release and later compression. Lead may be altered to bring all the events a little earlier or a little later, the former being generally used. Decreasing travel results in an opposite effect on each event of the stroke.

### Two Types of Governors

There are two main types of governors in use, known as the fly-ball and shaft governor. In most Corliss engines the flyball has the centrifugal force of the balls working against gravity, but for higher speeds or more sensitive regulation or for other than vertical positions the spring is substituted.

Although the details of shaft governors vary widely, they may be classed as two main types; those which use centrifugal force only and those in which this effect is combined with inertia. As a rule the centrifugal governors are used where the eccentric is revolved around the shaft, controlling a riding cut-off valve.

For controlling the valve of a single-valve engine, power is required which means a heavy governor weight and it has been found best to take advantage of the inertia of this weight to increase the quickness of action.

In any form of shaft governor, changing the spring attachment changes the sensitiveness and changing the weight adjustment changes the speed. In the centrifugal form, increasing the spring tension and the weights will

increase sensitiveness or attachment of spring or weights may be changed so as to give them greater leverage about the pin, which has the same effect as changing the tension or weight.

### Action of Flyball Governor

In Fig. 54 is shown a flyball governor of the type used on Corliss engines. This governor has an automatic safety

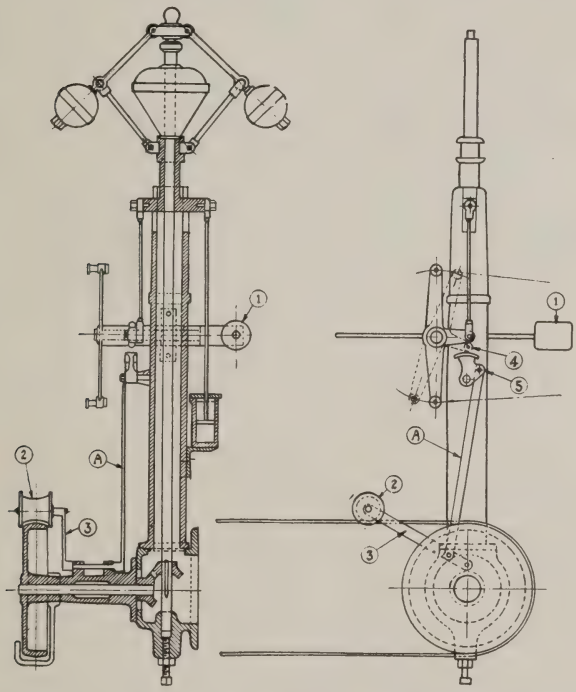



FIG. 54. ONE TYPE OF FLYBALL GOVERNOR USED WITH CORLISS ENGINES

stop and when the engine is at rest the lever 4 rests on the automatic rest 5. This automatic rest is held in place by the rod A and the arm 3 which is connected to the idler pulley, 2, resting on the governor belt.

Should the governor belt break, the idler pulley will drop down pulling the automatic rest 5 from under lever 4 and allowing the lever to drop far enough to bring the

TABLE III. VARIOUS ADJUSTMENTS OF FLYBALL GOVERNORS AND THEIR EFFECT

| Part | Pulley or gear | Balls | Spring tension or weight load | Change weight for spring | Load and speed | Leverage | Take-up in linkage | Dash-pot |
|---|---|---|---|---|---|---|---|---|
| Change..... | Increase driving or decrease driven pulley or gear size | Increase weight of balls | Increase tension or load | Substitute weight load for all or part of spring load | Governor driven faster and more heavily loaded | Increase radius of lever attached to drop rod | Decrease valve opening for given governor position | Smaller opening or heavier oil |
| Main effect... | Decreases engine speed | Makes simple governor more powerful but more sluggish | Engine faster | Governor more sluggish | Governor more sensitive, engine speed may be the same | Governor less sensitive | Engine slower | Governor more sluggish |
| Other effects.. | | With loaded governor, engine slower, less sensitive | With weight load, governor slightly more sensitive | Less likely to vibrate | Governor more likely to hunt | Governor more powerful | Governor operating position different | Less likely to hunt |
| Change..... | Decrease driving or increase driven pulley or gear size | Decrease weight of balls | Decrease tension or load | Substitute spring for all or part of weight load | Governor driven slower and less heavily loaded | Decrease radius of lever attached to governor drop rod | Increase valve opening for given governor position | Larger opening or lighter oil |
| Main effect... | Increases engine speed | Makes simple governor less powerful, less sluggish | Engine slower | Governor more prompt | Governor less sensitive, engine speed may be the same | Governor more sensitive | Engine faster | Governor more prompt |
| Other effects.. | | With loaded governor, engine faster, governor more sensitive | With weight load governor slightly less sensitive | More likely to vibrate | Governor more stable | Governor less powerful | Governor operating position different | More likely to hunt |

safety block on the knock-off lever of the Corliss valve gear under the tail plate on the grab hook so that the hook plates clears the catch block and the steam valve will not open. By this arrangement the engine is ready to start and the safety device is always ready for action without any attention from the operator. The running speed of the governor is 125 r. p. m. By moving the adjusting weight 1 in or out, the speed of the engine may be increased or decreased several revolutions.

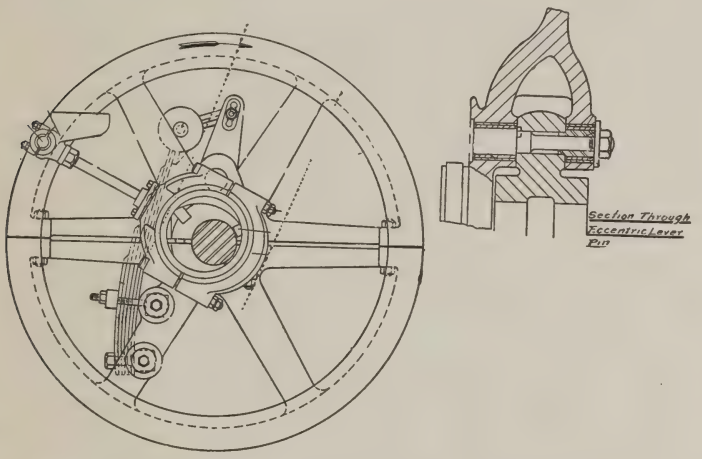



FIG. 55. ROBB-ARMSTRONG-SWEET TYPE OF SHAFT GOVERNOR

In table III are shown some of the results which may be expected in making changes in the adjustment of fly-ball governors.

Several types of shaft governors are in use which operate on the same principle but differ in mechanical details. In Fig. 55 is shown a Robb-Armstrong-Sweet type of shaft governor. The eccentric lever for this governor is of the double bearing type with a bearing on either side of the wheel arm to prevent the overhanging weight of the lever from wearing the pins and bushing out of alinement.

It is possible to increase the speed of the engine by increasing the tension on the main governor spring, and to decrease the speed by decreasing the tension. If it is found that the governor is too sensitive to variation of

loads, this can be corrected by moving the link in the eccentric lever one hole further from the shaft and, if it should be found that the governor is too sluggish in action or not sensitive to variation of load, allowing a variation of speed in the engine, the link in the eccentric lever, may then be moved one hole nearer the eccentric shaft.

An important factor in satisfactory operation of the governor is the position of the fulcrum on the main governor spring. If the governor should be unsteady or have a tendency to hunt or race, this may be corrected by swinging the point of the fulcrum further towards the spring weight and again locking it in position.

Shaft governors, employ, for their operation, forces of two kinds, first centrifugal force and second inertia. In this respect they differ from flyball governors which employ centrifugal force, only.

### Most Shaft Governors Use Inertia

While it is possible to design shaft governors which use only centrifugal force to control the speed of the engine, it has been found that the governor weight must be made so heavy that the governor is correspondingly slow or sluggish in its action. It is for this reason that nearly all shaft governors are so designed that the inertia of the weight will assist the governor in changing position.

In governors of this type, advantage is taken of the tendency of a weight to keep on moving at the same speed when the speed of the flywheel changes. If the engine is running at a constant speed, the fly wheel and governor weights will be turning at the same rate. If a load is suddenly thrown on the engine, the flywheel speed slackens but the inertia of the governor weights causes them to move forward at the same rate as before. This movement is utilized by some mechanical means depending on the particular design of the governor.

### Classification of Shaft Governors

The shaft governor may be classified with respect to the arrangement of weights employed, as follows: 1. Balanced governors with two weights and their fly wheels in continual balance. 2. Balanced governors with a single weight and their fly wheels not in continual balance. 3.

Governors with a single arm which carries inertia weight, centrifugal weight and eccentric; the governor and its wheel being nearly balanced in all positions. 4. Governors having two arms or an arm and a weight, the governor and its wheel being nearly balanced in all positions.

Governors of all of the above classes can be so operated that the regulation can be either assisted or retarded by

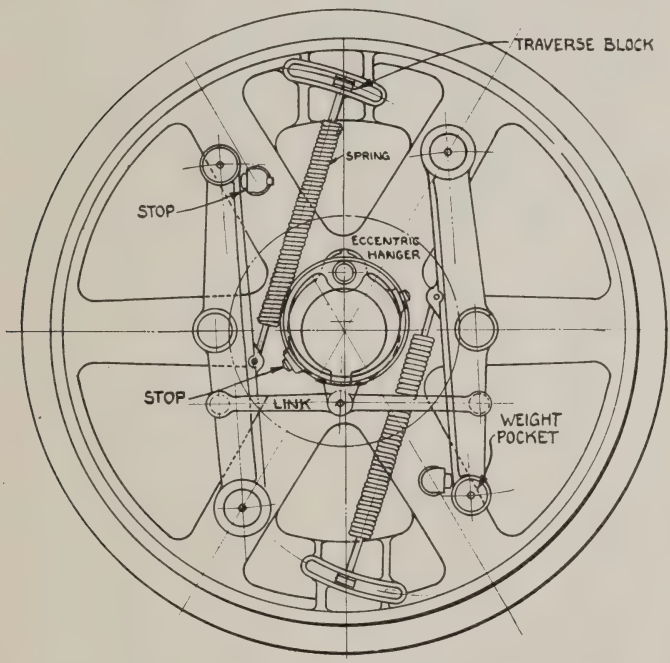



FIG. 56. HARRISBURG BALANCED TYPE SHAFT GOVERNOR

inertia and can be connected to a rotating or a swinging eccentric as desired. In most of the governors used, however, inertia assists the regulation.

In Fig. 56 is shown another type of shaft governor, of the centrally balanced centrifugal inertia type. In this type the weight arms are constructed with differential weight pockets to allow a considerable range of speed adjustment without altering the tension of the springs. If an increase of speed is desired, remove weights of equal

TABLE IV. PRINCIPAL ADJUSTMENT OF SHAFT GOVERNORS

| Part | Spring | | Weight | Weight and spring | |
|---|---|---|---|---|---|
| Change | Substitute heavier spring or increase spring leverage | Increase tension of same spring | Increase centrifugal weight or weight leverage | Increase weight and substitute heavier spring | Increase weight and tension on same spring |
| Effect on engine speed | Faster | Faster | Slower | May be the same | May be the same |
| Effect on governor | May be the same | More sensitive | More sensitive | More powerful | More sensitive, less stable |
| Change | Substitute lighter spring or decrease spring leverage | Decrease tension of same spring | Decrease centrifugal weight or weight leverage | Decrease weight and substitute lighter spring | Decrease weight and tension on same spring |
| Effect on engine speed | Slower | Slower | Faster | May be the same | May be the same |
| Effect on governor | May be the same | Less sensitive | Less sensitive | Less powerful | Less sensitive, more stable |

thickness from the two weight pockets of the lever and, to obtain a decrease of speed, add weights of equal thickness. If an increased number of revolutions causes the governor to race, move the attachment block, in the slot to which the outer end of the spring is attached, farther from the small end of the weight lever. If this does not entirely correct the sensitive condition, the plug is screwed into the spring until the racing ceases.

If the decrease of speed so obtained renders the governor too sluggish in action, move the attachment or traverse block in the slot in the opposite direction. If this does not improve the regulation and the speed is lower than desired, weights of equal thickness are added increasing the spring tension until the proper speed is obtained.

Table IV shows the effect on shaft governors due to changing the spring tension or making a change in the governor weights.

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